This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

NYU RESEARCH LIBRARIES
3 3433 06636663 8

PRACTICAL HANDBOOK

ON

PUMP CONSTRUCTION.

BY

PHILIP R. BJÖRLING.

WITH NINE PLATES.

E. & F. N. SPON, 125, STRAND, LONDON.

NEW YORK: 35, MURRAY STREET.

1887.

THE NEW YORK
PUBLIC LIBRARY
518481 A
ASTOR, LENOX AND
TILDEN FOUNDATIONS
R 1931 L

THIS LITTLE BOOK

IS

WITH KIND PERMISSION

Dedicated

TO

HENRY DAVEY, ESQ., M.I.C.E., M.I.M.E., ETC., ETC.,

OF LEEDS,

AS A SLIGHT TOKEN OF ESTEEM,

BY

THE AUTHOR

NOV 15 '30

PREFACE.

"WHERE can I obtain a Practical book on Pumps?" This oft-repeated query addressed to me by numerous gentlemen with whom I have become acquainted in the execution of my professional duties in this special line, has induced me to offer what varied and extensive experience has taught me to be the main basis upon which Pumps, such as herein described, should be constructed. Being unable myself to obtain the particulars required in cases of this description in book form, it is with a hope that a lucid and graphic description of those main points which form a safe and effective guide for the construction of first-class Pumps, will prevent the production of those abortive pieces of machinery, designated by courtesy, Pumps, that the notes of some sixteen years have been condensed into what I hope will prove to be a handy book for reference or consultation.

It is also hoped that this small manual will find a welcome at the hands of those who have the practical part to perform, as well as those who either undertake or superintend the designing.

I have to thank Henry Davey, Esq., for kindly looking over and correcting the matter, and any alteration that may be deemed at all beneficial to the readers, will be gladly accepted and considered, with a view to future editions.

P. R. B.

MUCH WENLOCK, SALOP, 1886.

CONTENTS.

	PAGE
PRINCIPLE OF THE ACTION OF A PUMP	1
CLASSIFICATION OF PUMPS	3
DESCRIPTION OF VARIOUS CLASSES OF PUMPS	4
REMARKS ON DESIGNING PUMPS	14
MATERIALS PUMPS SHOULD BE MADE OF FOR DIFFERENT KINDS OF LIQUIDS	16
DESCRIPTION OF VARIOUS CLASSES OF PUMP-VALVES	23
REMARKS ON DESIGNING PUMP-VALVES	37
MATERIALS PUMP-VALVES SHOULD BE MADE OF FOR DIFFERENT KINDS OF LIQUIDS	42
DESCRIPTION OF VARIOUS CLASSES OF PUMP BUCKETS	45
REMARKS ON DESIGNING PUMP BUCKETS	48
DESCRIPTION OF VARIOUS CLASSES OF PUMP PISTONS	49
CUP-LEATHERS	52
AIR-VESSELS	53
RULES AND FORMULAS	54
MEMORANDA	65
TABLES	67
ILLUSTRATIONS	*At end*

PRACTICAL HANDBOOK

ON

PUMP CONSTRUCTION.

PRINCIPLE OF THE ACTION OF A PUMP

ERRATA.

Page 4, line 19, *for* "Plate VII." *read* "VIII."
„ 11, „ 23, *for* "Figs. 11, 12, and 13" *read* "10, 11, and 12."
„ 12, „ 21, *for* "Figs. 14 and 15" *read* "13 and 14."
„ 13, „ 24, *for* "of the annular space" *read* "to the annular space."
„ 19, „ 20, *for* "a cork" *read* "a cock."
„ 35, „ 3 from bottom, *for* "to tighten the ball" *read* "to lighten the ball."

[illegible] in the suction-pipe. The valve in the bucket is kept shut by the pressure of the air above it, while the suction-valve will be forced upwards by the water rising into the barrel, which water is forced into the space otherwise forming a vacuum under the bucket by the air pressing on the exposed surface of the water in the well; in other words, by abstracting the pressure of the air from off part of the surface of the water, that portion

PRACTICAL HANDBOOK

ON

PUMP CONSTRUCTION.

PRINCIPLE OF THE ACTION OF A PUMP.

A PUMP in its most common form, as shown at Fig. 1, Plate I., consists of a barrel, bored perfectly true and parallel, into which fits a bucket. This bucket is fitted with a valve which opens upwards; a valve is also fitted at the bottom of the barrel, which also opens upwards. This latter valve is called the suction-valve, or perhaps, more commonly, the sucker.

The action is as follows:—When the bucket is raised in the barrel by means of the handle, a partial vacuum is formed under it, more or less complete according to the perfection of the working parts and tightness of the joints in the suction-pipe. The valve in the bucket is kept shut by the pressure of the air above it, while the suction-valve will be forced upwards by the water rising into the barrel, which water is forced into the space otherwise forming a vacuum under the bucket by the air pressing on the exposed surface of the water in the well; in other words, by abstracting the pressure of the air from off part of the surface of the water, that portion

under the bucket is forced upwards by the pressure on the remaining portion of its surface. Supposing the up-stroke of the bucket completed, and the space under the bucket is filled with water; on commencing the down-stroke the water cannot return through the suction-valve, for it will shut immediately by the weight of the water, but the bucket-valve will open by the same effort. Thus the water will be forced from the under side to the top side of the bucket. It can be easily understood that the water above the bucket can be raised to any height required; but the height to which the water under the bucket can be raised above the natural level of the water in the well is limited by the law of nature within the range of 30 to 33 feet; that is, if the vacuum could be obtained perfect, there could not be more than 30 to 33 feet from the surface of the water in the well to the under side of the bucket, when it is at the top of its stroke. A comparison of the relative weights of water and air would appear to warrant us placing the suction-valve of a pump at a greater height above the surface of the water in the well or pit than is usually adopted in practice, but the imperfections of the different parts of the pump do not admit of it being carried beyond from 20 to 25 feet; the author, however, prefers two pipes, each 9 feet long, or 18 feet.

CLASSIFICATION OF PUMPS.

he pumps mentioned in this little treatise may first be ded broadly into Vertical and Horizontal.

ertical Pumps are again divided into:

1. Ordinary Suction Pumps or Bucket Pumps.
2. Suction and Lift Pumps.
3. Plunger Pumps or Force Pumps.
4. Bucket and Plunger Pumps.
5. Piston and Plunger Pumps.

orizontal Pumps are divided into:

1. Double-acting Piston Pumps.
2. Single-acting Plunger Pumps.
3. Double-acting Plunger Pumps.
4. Bucket and Plunger Pumps.
5. Piston and Plunger Pumps.

DESCRIPTION OF PUMPS.

VERTICAL.

Ordinary Bucket Pump.

Fig. 1, Plate I., illustrates an ordinary *hand*-pump actuated by a lever: A is the barrel; B the bucket fitted with an ordinary leather clack-valve; C is the suction-valve; D the suction-pipe; E delivery spout; F the lever or pump-handle; G fulcrum; and H the bucket-rod. The bucket enlarged is shown in Figs. 39 and 40, Plate VII., and the valve in Figs. 17 and 18, Plate V.

Vertical Bucket Pump used in Mines.

This pump is illustrated in Fig. 2, Plate I., in which A represents the pump "trees" or rising main; B the working barrel; C the "drop clack-piece"; D the clack-piece proper; E the suction-pipe or windbore, fitted with a strainer F; in this case the windbore is of the sliding type used for sinking purposes. The bucket usually adopted for this class of pump is shown enlarged in Figs. 41 and 42, Plate VII., and the clack in Figs. 20, 21, and 22, Plate V.

The "pump trees" for the bucket pumps should always be made about one inch larger in diameter than the working barrels in order to obviate the friction which would occur when the buckets have to be lowered or drawn, supposing the latter were made the same diameter. The pump trees are usually made of 9-feet lengths of pipe, with a few matching or making-up pieces 6 feet

l 3 feet long for convenience of fixing. They are ıerally flanged, but sometimes made with spigot and ıcet joints. The joints are commonly made by lead or ought-iron rings wrapped round with old flannel or mmon woollen cloth soaked in tar, and when screwed ı makes a perfect water-tight joint, and can be separated d remade with great facility. For heavy pressures, ıwever, there is no joint as good as the guttapercha rd joint.

If the water which the bucket pump has to lift is ghly charged with acid, the rising main is frequently ade much larger in diameter and lined with staves of ood fitted with great care, otherwise the cast-iron pipes ill soon be eaten away by the corrosive action of the ıid. The staves are put round the interior of the pipe, narrow space being left between the first and the last ave; into this space are driven two wedge-shaped pieces, ıe driven in from each end of the pipe.

The working barrel is usually made of cast iron, but hen the water to be lifted is contaminated with acids, it ould be made of solid gun-metal; but as this is too ex- ınsive for large pumps, it is made of cast iron lined ith brass or gun-metal, and where the water is very bad ıosphor-bronze is used. It must be bored perfectly true ıd parallel, so that the bucket can work up and down ith ease and with as little friction as possible; it must ı bell-mouthed or trumpet-shaped at the top, to allow e bucket to enter easily without injuring the bucket ather when lowered down.

Sometimes a door is provided above the working ırrel for access to the bucket, so as to prevent having to ·aw the bucket out at the top of the pit.

The clack-piece is also provided with a door for access the suction-clack. Between this clack-piece and the

working barrel is sometimes introduced another piece, into which is dropped an auxiliary fixed clack, in case something should happen to the proper clack, and the clack-door should be under the level of the water in the mine. The seat in this clack-piece is a little less than the bore of the working barrel and bored slightly taper, so that it can be drawn from the top.

The ordinary windbore consists of a pipe, furnished at the bottom with an enlargement perforated by holes, which prevents any large pieces of foreign matter from entering the pump and getting into and hanging the valves. This bottom part is either egg-ended, as shown in Fig. 2, Plate I., flat-bottomed or round, and for very small pumps the suction-pipe is frequently plugged up at the bottom and holes drilled in it. The aggregate area of the holes in the windbore should be at least one and one-half times the area of the suction-pipe; for sewage purposes they ought to be not less than twice the area.

The sliding windbore illustrated in Fig. 2, Plate I., is made of cast or wrought iron, the latter preferably, although it is more expensive, on account of its lightness. It is used for sinking purposes. It consists of a cast-iron pipe bolted to the suction branch of the clack-piece. This pipe is turned perfectly true and parallel to work freely in the stuffing-box and gland, which are bolted to the outer sliding pipe, the gland and stuffing-box being bored true to fit the pipe. If this pipe is of cast iron the strainer is usually cast in one with it, but if of wrought iron it finishes with an L iron ring, to which a loose strainer is bolted or riveted. The fixed pipe is made 10 feet long, to allow the sliding pipe to lower 9 feet, and when the sinking has proceeded thus far a 9-feet length of suction-pipe is inserted, then the windbore is again allowed to sink 9 feet, and so on until the suction has reached its

limit, when the suction-pipe is removed, the pump lowered, and the previous process repeated. The strainer for sinking purposes is usually egg-ended or heart-shaped.

Vertical Plunger Pump.

A *small vertical plunger pump*, such as is used for boiler feeding and for purposes where a small quantity of liquid has to be raised, is illustrated in Figs. 7 and 8, Plate II. Fig. 7 is a sectional elevation and Fig. 8 is a plan. The construction is so very simple that the illustrations will explain themselves. A great error which often is overlooked in these pumps is that the designer, for the sake of uniformity in the appearance, places the centre of the suction and delivery branches in one line, and thereby forms an air-lodge, which is a great detriment to the quantity of liquid raised.

It will be seen in Fig. 7 that the suction branch is low down and the passage from the same to the barrel is at the top of the latter, and that the passage from the barrel to the delivery valve is also at the top, leaving no place whatever where any air can be kept, for it always rises to the highest point. The valves and seats are not shown in the illustration, because they alter in design for different liquids and pressures against which the pumps have to work.

Vertical Plunger Pumps used in Mines.

This pump is shown in Fig. 3, Plate I. It consists of a pole-case or plunger barrel, fitted at the top with a stuffing-box and gland bored accurately to fit the plunger. The case is made, according to the diameter of the plunger and the length of the stroke, from one to two inches larger internal diameter than the plunger.

The plungers are sometimes made of cast iron fitted with a centre bolt; sometimes a boss is formed at the top of the plunger, into which the pump-rod is cottered; in small pumps the rod is in many cases screwed into the boss and secured by a back nut. In very small pumps the plunger and rod are made in one forging. The best plan is to carry the rod through the plunger and secure it by means of a nut and split cotter.

In Cornwall the plungers mostly consist of wood spears or rods covered with cast-iron casing, turned perfectly true and parallel, and secured to the rod by means of wood wedges. This plunger is shown in Fig. 3, Plate I.

The plunger-case is bolted to the top flange of one branch of the double pipe or H-piece, and to the bottom flange below is secured a pipe of the same diameter as the plunger-case, this pipe being blocked up at the bottom and provided with a foot; this pipe is also useful for collecting the sediment; a blow-off cock should be provided at the bottom, so that the sediment can be blown out at intervals when necessary. The other pipe of the H-piece is fitted with the suction-clack and a door for easy access to the same.

The suction-pipe or windbore is bolted to the flange below the suction or bottom clack.

To the top of the same branch of the H-piece is secured the rising main or pump "trees."

There is one objection to this design of plunger pump, namely, that the delivery clack is placed below, leaving a space above it round the plunger for air, and to allow this air to escape the packing in the stuffing-box must be left slack enough to allow the air to pass through it. The delivery clack ought to be placed just below the stuffing-box, and the internal diameter of the pole-case should be twice the area of the plunger. There should be a cup

formed round the top of the plunger gland for water to prevent the air passing through the gland and stuffing-box into the pole-case on the up-stroke of the plunger.

The action of the plunger pump is as follows:—On the up-stroke of the plunger the water enters from the sump or tank by the windbore (which in this case is flat bottomed, and not sliding, as shown in Fig. 2, Plate I.), passes through the suction-clack, the double-pipe or H-piece, into the space left under the plunger; and on the down-stroke the water is forced through the delivery pipe, up the rising main, and delivered at the top of the same, either into a tank, from which the next set gets its water, or into a collar launder or spout at the top of the pit mouth.

The Hollow Plunger Pump.

The hollow plunger pump is a combination of the bucket pump and the plunger pump. It is illustrated in Figs. 4, 5, and 6, Plate I. Fig. 4 is a sectional elevation, Fig. 5 an enlarged view of the top of the plunger, and Fig. 6 the plan of the delivery valve. The plunger-case is similar to the ordinary one, and fitted at the top with a stuffing-box and gland; to the top of the stuffing-box is secured a delivery clack-piece furnished with a door for access to the delivery valve, and to the top of this clack-piece is bolted a cover provided with a stuffing-box and gland for the pump-rod (not shown in the illustration).

The plunger consists of a hollow pipe without flanges, turned all over perfectly true and parallel; it is furnished at top and bottom in the inside with two lugs, through which pass two wrought-iron rods provided at the bottom with double nuts, and at the top secured to a cross-head forged on the main pump-rod and secured by double nuts.

The delivery valve, in this example of hollow ram

being one-half the area of the bucket, one-half of the water passes through the delivery valve and the other half remains in the top part of the barrel round the plunger. At the next up-stroke the other half of the water will be lifted through the delivery valve, whilst the part under the bucket is again filled.

Horizontal Pumps.

Double-acting Piston Pump.

This pump is illustrated in Figs. 10, 11, and 12, Plate III. This class is most commonly used for direct-acting steam pumps; it is double-acting, takes up very little space, and is very good when you have to deal with clean water; but when the water is dirty or gritty, the leathers in the piston soon wear out and cause a great deal of trouble and waste of time, which latter is particularly a considerable disadvantage in coal-pits or mines.

This pump generally consists of a working barrel cast in one with a rectangular shaped valve-box, and rectangular passages leading from the working barrel to the valve-box; this is a very bad design indeed, because there are so many flat surfaces, compelling the designer to make them very thick, so as to be able to stand the pressure.

The one shown in Figs. 11, 12 and 13, Plate III., is a type the author strongly recommends. It consists of a working-barrel A, two suction-valve boxes BB, jointed at the bottom by a suction-pipe C, furnished with a suction-branch or inlet D. The delivery valve boxes EE are fixed directly over each end of the barrel. These boxes again are joined by a pipe F, furnished with a delivery branch or outlet G, on the top of which the air-vessel is secured by bolts. The suction-valves are accessible by means of the covers HH, and the delivery-valves through the covers JJ.

It will be seen in the cross-section, Fig. 12, Plate III., that there are no places where the air can lodge, and that any air contained in the water must enter into the air-vessel, and there replenish the air which has been absorbed by the water and passed away from it.

Single-acting Plunger Pump.

The single-acting plunger pump is illustrated in Fig. 15, Plate IV. This pump is undoubtedly the best plunger pump. It consists of a cast-iron working barrel; on the top of one end is a branch fitted with a delivery valve box. The suction-valve box is cast in one with the back cover of the barrel. Both the suction and delivery valve boxes are fitted with covers for easy access to the valves for repairs or renewal. The peculiar feature in this pump is that the centre line of the plunger is below the centre line of the working barrel, and the area of the barrel is twice that of the plunger. It will be seen also that the water is rising all the way during its passage through the pump, and that there are no air-lodges present at any part of it.

Double-acting Plunger Pump.

This pump is illustrated in Figs. 14 and 15, Plate IV. It consists of two working-barrels, which are firmly bolted to a strong bed-plate by means of well-ribbed feet. Each barrel is furnished with a delivery branch on the top, and a suction branch on the side, the top of the latter branch should be placed level with the top of the working-barrel to prevent air-lodge. One of the barrels is provided with a stuffing-box and gland for the pump-rod at one end, and a gland and stuffing-box for the plunger at the other end. The other barrel is furnished with a stuffing-box and gland for the plunger at one end and a cover for the introduction of the plunger at the other. The plunger is *turned perfectly* true and parallel to work in the stuffing-

boxes and glands, which are bored to receive it. When bad water is raised, it is sometimes covered with brass, gun-metal, phosphor-bronze, or copper, and at other times made of solid gun-metal. All the valve-boxes are cast separate and bolted to their respective branches provided on the working-barrels. All the surfaces are round, to withstand heavy pressures. The valves are made of different material and are differently constructed according to circumstances.

Piston and Plunger Pump.

This class of pump is illustrated in Fig. 16, Plate IV. The principle of this pump is similar to the bucket and plunger pump described on page 10, and illustrated in Fig. 9, Plate II. It consists of a working-barrel in which works a piston. The rod is enlarged to form a plunger one-half the area of the piston.

The action of the pump is as follows:—Supposing that the piston is moving from left to right; then the suction-valve opens and allows the water to fill the working-barrel. As soon as the piston reverses its motion and travels from right to left the water is forced through the delivery valve; but as the plunger is only half the area of the piston, one-half of the water will pass through the top passage of the annular space round the plunger; the remaining half will pass into the delivery pipe. When the piston is again reversed, that is, travelling from left to right, the water that remained round the ram is delivered through the rising main. It will be seen that this, like the bucket and plunger pump, only sucks once in each revolution of the crank, or double stroke if the pump is direct-acting, but delivers twice; so that it is a double-acting delivery with only two valves, the quantity of water discharged being equal to a double-acting piston-pump having a piston of the same diameter as the ram.

REMARKS ON DESIGNING PUMPS.

The *space between the suction-valve* and *bucket, plunger*, or *piston*, as the case may be, should be as little as possible, consistent with ample waterway being given.

All *passages* should be as *straight* as possible, and when bends are necessary, the radius should be an easy one.

Sudden enlargements and *contractions* in the passages should be avoided, but if an alteration in size or shape of the passages is necessary, it should be made gradually.

Care should be taken that the *suction-pipe* should be the *lowest* point in the pump, and in no case must there be any part of the suction portion of the pump above the top of the barrel, and the delivery passages should be above the top of the barrel, so that there is no place for air to lodge, as *air-lodges* affect the *efficiency* of the pump.

There must be *no* part of the *suction-pipe higher than the suction branch* on the pump.

If the pump is required to raise *hot water*, there should be very little suction; in fact, it is best, if possible, to have the water running into the pump.

Long suction-pipes should always be provided with a *foot-valve* just above the windbore or strainer, in the well or pit.

Great care must be exercised to have *equality of metal* all through the pump, and where a greater or less strength is required, the alteration from one to the other must be gradual.

All *corners* should be *well rounded*, with a radius greater than the thickness of the metal.

There should be as *few flat surfaces* as possible, and where there are any they should be well ribbed.

Joints in the *suction-pipes* and the *suction part of the pump* must be very *carefully* made, and *perfectly tight*, as great damage and annoyance is often caused in this way by badly made joints.

Change of *direction* in the *flow of the water* should be avoided as much as possible. After a current of water has received an impulse, it is necessary that the motion imparted should be continued with a uniform velocity throughout its whole course; any change in that velocity will cause considerable loss in power by overcoming the inertia. The motion of a crank moving in a circle with uniform speed is therefore an imperfect machine for moving a pump-piston, because the motion which it imparts changes at every point of its course. The changes of a piston should be sudden, and its velocity uniform. If any irregularities in the motion of a pump-rod are advantageous, it is the reverse with the motion of a crank.

In *vertical pumps* the delivery valve box should always be at the *highest* part of the working-barrel.

MATERIALS OF WHICH PUMPS SHOULD BE MADE, AND THE CLASS OF PUMPS FOR DIFFERENT LIQUIDS.

For *strong acids*, single-acting plunger pumps made of earthenware, stoneware, glass, guttapercha, or cast iron lined with guttapercha.

Earthenware or *stoneware* pumps are of the plunger type, the plunger and the pipe-joints being made with asbestos. The packing gland and all the joints are either made by flanges, by collars much smaller in diameter and tightened by means of wrought-iron rings, bolts and nuts, or by spigot and socket, like ordinary stoneware piping. The plunger, valves, and seats are accurately ground together. When these pumps are used for forcing thick and viscid liquids, they should never make more than eighteen to twenty strokes per minute, but if used for thin acids, they can be driven at the usual speed for water pumps.

Glass Pumps.—These pumps are of the single-acting bucket type; the barrel is made of the best plate glass, bored and polished perfectly true and parallel; the top and bottom chambers are made of lead if strong acids are to be pumped. The chambers are furnished with lugs, and are held together by wrought-iron tie-bolts, with double nuts, one on each side of each lug. The top chambers are also provided with a flange for the delivery pipe, and the bottom chamber for the suction-pipe.

Sometimes the *acid* is raised by means of a *double-acting air-pump*. The acid eggs are filled with acid by gravity

tion; when the egg is full, the delivery pipe of the pump is set in communication with it and the pump forces air into the same, and by that means elevates the acid to the tank or cistern without passing through the pump.

For *Weak Acids*, double-acting piston pumps, and plunger pumps; all parts made of gun-metal.

For *Ammoniacal Liquor*, any type of pump will do, but they must be made of cast iron. The same also applies to *Anthracene Oil.*

For *Beer*, bucket pumps are generally used, made of gun-metal throughout for small pumps, but if large, they are for cheapness made of cast iron with gun-metal or gun-metal lined barrels.

For *Benzole*, double-acting piston pumps made of cast iron, working-barrels lined with brass, or if the pumps are very small, wholly of gun-metal.

For *Benzoline*, double-acting piston pumps, or single, double or treble-barrel bucket pumps, made of cast iron with gun-metal or gun-metal lined working-barrel or barrels.

For *Bleaching Mills*, double-acting piston pumps, or treble-barrel bucket pumps, of cast iron, with the barrel or barrels of gun-metal or lined with gun-metal.

For *Bore-holes.* These pumps are of the single-acting bucket type, and consist of a wrought-iron suction pipe the upper part of which is screwed into the bottom of a gun-metal, or cast-iron gun-metal-lined working-barrel, the top being screwed into a wrought-iron delivery pipe or rising main, through which the pump-rods pass. The joints in the suction-pipe and rising main are flush both inside and out. The lengths of pump-rods are the same as the rising main, and coupled together either by brass sockets or screwed into one another. These pumps sometimes deliver the water at the top of the well; in other cases, when the water has to be forced above that

point, a delivery chamber must be bolted on the top of the rising main, and this chamber be provided with a cover furnished with a gland and stuffing-box, and a flange for receiving the delivery pipe.

For *Breweries*, treble-barrel plunger pumps, treble-barrel bucket pumps, or horizontal double-acting piston pumps, with all the parts made of gun-metal.

For *Creosote*, double-acting piston pumps, or single, double, or treble-barrel bucket pumps, made entirely of cast iron.

For *Domestic purposes*, the ordinary bucket pump made of cast iron.

For *Drainage*, almost any class of pump, but the best is the double-acting piston pump or treble-barrel plunger pump, placed horizontally on a massive frame. All parts may be made of cast iron.

For *Dyeworks*, double-acting piston pumps; the material for their construction depends upon the chemical properties of the dyes to be raised.

For *Fire Engines*, the best type of pump is, without doubt, the bucket and plunger type; but for direct-acting steam pumps, the double-acting piston pump has done very good service, the best being made of gun-metal with copper air vessel, but pumps of cast iron with working-barrels lined with brass or gun-metal are very often used.

For *Gasworks*, double-acting piston pumps, double-acting plunger pumps, or piston and plunger pumps; all parts made of cast iron.

For *Gelatinous fluids*, double-acting piston pumps or piston and plunger pumps, made of gun-metal or cast iron lined with gun-metal.

For *Glutinous fluids not containing acids*, plunger pumps, single, double, or treble-barrel; they should be made of cast iron throughout.

For *Irrigation*, see Drainage, page 18.

For *Malt Liquor*, see Breweries, page 18.

For *Milk of Lime*, the double-acting piston pumps, or the double-acting plunger pumps are the best; they should be made entirely of gun-metal, but on account of the great expense they are usually made of cast iron, the working-barrel being lined with brass or gun-metal.

For *Mines*, the large vertical bucket pumps, the plunger pumps, the horizontal double-acting piston pumps are used; but the best are the *horizontal double-acting plunger pumps* for the following reasons:—

First. There is less friction in the ram working through a stuffing-box than in the bucket working against the inside of the pump barrel.

Second. When the water, as is generally the case in collieries and mines, is impregnated with sand, grit, mud, and other foreign matter, the wear and tear of the plunger is prevented by the space underneath it forming a receptacle for the solid matter, which is not the case in the piston pump. A cork should be provided on the under side of the barrels, so that the sand or sludge can be blown off at intervals, when necessary.

Third. The cost of repacking the ram is only nominal, but the cup-leathers for the pistons are a great expense.

Fourth. The ram being packed from the outside, leaks are immediately detected, and the glands can be tightened in a minute while the pump is running, and the stuffing-box repacked in a very short time, whereas in a piston pump a great leakage can be going on for a long time without being noticed, representing so much duty lost; a great deal of time is also lost in putting in new cup-leathers, or taking off the worn piston or bucket and putting in a new one.

Lastly. That the ram can be lubricated, and the corroding action of acidulated water greatly reduced.

The *Bucket Pump* is very useful, and mostly employed for sinking or for the bottom lift in a mine, where there is any danger of a sudden inburst of water. The working-barrel should be made of very hard metal, and the length of the rods nicely adjusted, so that the leather of the bucket will come slightly above the bore in the up-stroke; if the water is clean and not contaminated with acid, and the lift not too great, then the bucket pump is probably the best. The occurrence of air getting into the pump does not cause the shock which is experienced with plunger pumps.

The *objections* to these pumps are, however, very great, namely:—

First. The rapid wear and tear of the leathers on the bucket, and the great expense in replacing them, especially if the bucket door is drowned; because all the rods must be drawn to the surface, which requires long time and necessitates the employment of a great number of men when the lift is deep.

Second. When the water is saline or acidulous, which is very often the case in Cornwall, the working-barrel is soon eaten away, which causes unevenness in the bore of the barrel, and causes a great leakage.

These are very serious objections, especially in mines where continuous working is an absolute condition.

For *Naphtha*, any type of pump will do, but they must be made of cast iron.

For *Oil*, the double-acting piston pump will do, but by far the best are of the single-acting plunger type; they should be made wholly of gun-metal.

For *Paper Pulp*, the double-acting piston pumps, or treble-barrel plunger pumps, made of cast iron.

For *Paint*, double-acting piston pumps or plunger pumps, made of cast iron, buckets or pistons fitted with cast-iron packing rings.

For *Petroleum*, single-acting bucket pump. The pump barrel is usually made of gun-metal or brass, but sometimes of cast iron, brass lined; the suction and delivery pipes are of wrought iron, the pump-rods are frequently made of wrought-iron tubes screwed together. Their diameters vary from 2 to 3 inches. They are worked by a tee bob or by a crank.

For *Salt Water*, any type of pump will do; all parts must be made of gun-metal, the alloy for which is given on page 42.

For *Sewage*, double or treble-barrel plunger pumps and double-acting plunger pumps, made of cast iron. The treble-barrel pumps give the nearest approach to equal flow, and consequently equal resistance, but on account of increased first cost, and the friction due from the three barrels, buckets and rods, it is better, whenever possible, to employ double-barrel pumps or double-acting piston pumps, and provide a heavy fly-wheel to equalise the resistance.

For *Sugar Solution*, double-acting piston pumps, and single, double, or treble-barrel plunger pumps, all parts made of gun-metal.

For *Tanneries*, single or double-barrel plunger, or piston and plunger pumps, made of cast iron, and barrels of brass, or lined with brass.

For *Tar*, see Gasworks, page 18.

For *Treacle*, see Sugar Solution, page 21.

For *Vinegar*, any class of pump will do, but they must be made of lead, glass, guttapercha, or stoneware; same as for acids, pages 16 and 17.

For *Waterworks*, double-acting piston pumps, bucket

and plunger pumps, and two or three single-acting plunger or bucket pumps, made of cast iron, working-barrels made of gun-metal, or cast iron gun-metal lined. For the objections to treble-barrel pumps, see Sewage, page 21.

The objections to the bucket and plunger pump is the friction produced by the bucket and plunger, which is nearly double that of the double-acting piston pump.

For *Wine*, any type of pump is suitable, but the bucket pump made of gun-metal is probably the best.

PUMP-VALVES.

The most important parts of a pump are its valves; let the design be good in all other respects, the performance of the pump will be seriously affected if the valves are of an unsuitable type, or bad in workmanship and design. A large portion of the power lost in a pump is mostly due to these defects; it is therefore very important that great care should be taken in designing to obviate them, and a careful choice made of the class of valves that are most suitable for the work to be done.

The duty of a pump-valve is twofold: Firstly, it should afford an unobstructed passage for the water in one direction; secondly, it should close the passage entirely, and prevent the return in the contrary direction. For a valve to fulfil the first condition, it must not contract the area of its waterway, or in any way obstruct the flow of the water; it must move with the same velocity as the water, and it must be of the same weight as the water it displaces, so as not to cause any resistance to the ascending water. To fulfil the second condition it must be heavy enough to close by its own weight before the pump commences the return stroke, so as to prevent the valve from banging; and it must have very little lift, in order to produce the least amount of slip.

It would be useless to advocate the universal adoption of one particular class, as the conditions under which they are employed are so numerous, that a single type would fail to fulfil all the requirements.

The number of different valves is legion, but the

Author will give only a few samples of the best and most commonly used.

The oldest valve is probably the metal clack-valve, as it is mentioned and illustrated in "Hero's" work on Pneumatics, written about the year 200 B.C. The most common is the leather clack-valve, which consists of a piece of leather or canvas covering an orifice and held down at one edge, which forms a hinge; the leather is at the centre covered top and bottom by metal plates, to make it rigid, and to add weight, so as to enable the valve to close.

The most simple valve for ordinary hand-pumps and pumps for very low lifts, is illustrated in Figs. 17 and 18, Plate V. It consists of a piece of leather or canvas cut to the same size as the diameter of the bottom flange of the pump-barrel, and a piece to the shape shown at A cut out; this slit must be cut so that a lap of one-tenth of an inch for every inch of the diameter of the waterway is allowed all round; a plate of wrought iron, cast iron, or gun-metal of the same diameter, should be placed on the top of the valve, and a plate of the same material a little less in diameter of the waterway must be placed on the bottom side, the two plates and the leathers are fastened together by a bolt or rivet, the former being preferable, as when the leather is worn out the nut can be unscrewed in a few minutes and a new leather put in. These valves should never be allowed to rise higher than an angle of 30° from the seat, and 60° from the horizontal line.

The Butterfly Valves.—These derive their name from the fancied resemblance to the wings of a butterfly, and are made in many different ways, some being of leather and canvas, with hinges formed out of the same piece; others of cast iron, wrought iron, or gun-metal clacks or flaps

faced with leather, canvas, indiarubbber, guttapercha, or vulcanised fibre, to reduce the severity of the concussion; others have beats of compressible substances fixed in the seat. Figs. 20, 21, and 22, Plate V., illustrate the best design of this type. A is the seat, B the guard, which prevents the clacks from rising too high; *c c* are the two clacks hinged on a pin; the holes in the clacks through which the pin passes are made oval, so that the clacks lift one-eighth of an inch perpendicular before they commence turning on the pin.

These two types of valves open by moving from a fixed point or hinge, therefore the lift or opening must be taken at the centre, and the periphery opposite the hinge of the valve passes through an arc double the length of the lift, consequently the valve takes a long time in closing, thus allowing a great amount of water to slip back into the suction-pipe before it has time to close, and a heavy concussion is produced. Valves of this class should be fixed in such a way that they open in the direction in which the water has to flow into the working-barrel; this prevents any change in the direction of the flow of the water.

Double-beat Clack-valves.—One form of this class of valves is illustrated in Fig. 19, Plate V. It consists of an ordinary clack-valve and seat, but having a hole half the area of the clack cut out of the top of it, this hole being covered with an ordinary clack-valve. Both these valves open in the same direction.

A modification of the above-described valve is shown in Fig. 23, Plate V. This valve is noiseless in its action and cheap. It consists, like the previous valve, of two clacks, but having the small one hung in the opposite direction. In this valve the area of the top clack is one-third the area of the opening in the main valve seat.

Valves with a perpendicular lift are mostly used for horizontal pumps, especially for waterworks. The most simple and best of this type is shown in Fig. 24, Plate V. This valve is called the conical mitre-valve. It consists of a conical shell, the sides of the cone being at an angle of 45°, the top part is turned to fit the bevel in the top of the seat, the lower part of the cone is furnished with three or more wings or guides, according to the size of the valve, these guides should be put at such an angle that the valve at every rise will partially rotate so as to wear the seat evenly and prevent any grooves being formed. Inside the cone is cast a short spindle, which beats against a stop provided in the pump-valve box.

This design of mitre-valve is by far the best, the flow of water being brought into the proper direction by reason of the cone causing less obstruction to its passage, and producing less contraction of the fluid vein than the valve illustrated in Fig. 25, Plate V. This valve consists of a slightly convex gun-metal disc, the periphery of which is bevelled to correspond with the seat, furnished with guides at its under side, and on the top side a spindle working in a guide above; and between the valve-plate and the bottom of the guide are placed alternately india-rubber rings and small round cast-iron or gun-metal washers; this arrangement forms a buffer spring, which diminishes to the least degree the knock produced by the valve at the end of its lift, it also assists the valve in closing on the return stroke—a most important feature, thereby adding an increased efficiency of the pump by reducing the amount of slip. Short indiarubber tubes are sometimes used in place of the rings and washers, also steel and brass springs, according to the chemical properties of the fluid to be raised by the pump. In all cases where springs are used a certain free lift should be given to the

valve, and the remainder should be obtained by the compression of the rubber rings or springs.

The surface of contact between the valve and its seat should be made perfect by grinding-in the valve after the seat has been fitted into its place. When both the valve and seat are of metal, without the intervention of loose beats, the valve and seat should be made of the same metal, otherwise a galvanic action is produced, causing corrosion of that surface, forming the positive element.

The spindle or spill-valve is represented by Fig. 27, Plate VI. It is similar to the last mentioned, with the exception that the guide on the under side consists of a round spindle or spill, working in a boss in the centre of the seat, fixed to the latter by ribs or webs. The objection to this valve is that the boss and its ribs take up a large portion of the waterway.

Sometimes these valves are made with a cone or hemisphere instead of a convex disc, as shown in Fig. 26, Plate VI.

A very useful valve for impure or thick fluids, such as tar, treacle, paper pulp, tan liquor, &c., is depicted in Fig. 28, Plate VI. It has a perpendicular lift, but, as will be descerned, has not any guides. It consists simply of an inverted bell without a clapper, hence its name, bell-valve, beating on a slightly countersunk seat. The bottom of the bell is made heavy, so that the centre of gravity is always below the bottom of the seat, guides not being then necessary. The top part only requires to be turned.

Another valve suitable for pumping sewage is illustrated in Fig. 29, Plate VI. It consists of an annular ring, which slides up and down a cylindrical guide secured to the valve-box cover, round the bottom part of the valve outside is secured a hard wood ring; to the inside of the

seat is also secured another hard wood ring, and the valve, instead of beating on the top of the seat, enters into it, to cut off any stringy matter that might be on the seat when the valve closes. The valve is prevented from rising too high by its ring coming in contact with the cover, and prevented from dropping too low by the ledge at the bottom of the guide cylinder.

Double-beat Valves.—These valves are either of gun-metal or cast iron, the latter being mostly used for large valves. They have two beats; one at the top, and one at the bottom: the area of the top seat should not be less than one-half the area of the bottom beat. In most of the London waterworks' pumps white-metal beats are employed; wood beats are frequently used, and of this class lignum vitæ, with the grain upwards, is the best, but beats made of the best English bark-tanned leather fixed to the valve and beating against a gun-metal seat are without any doubt the most durable valves for heavy pumping. Valves of this construction have been working for twelve months under heads of from 600 to 1000 feet in dirty water without requiring new leather beats.

This valve is illustrated in Fig. 30, Plate VI. The seating consists of a circular ring, on which the lower part of the valve beats, and a circular plate of about one-half the area of the bottom ring, on the outer edge of which the upper part of the valve beats; on the upper side of the top plate is cast a spindle, which rests against a boss on the under side of the valve-box cover. These two plates are joined together by three or more ribs or webs, according to the size of the valve. The valve itself may be described as a double cylinder, one contained within the other, but forming one entire piece, open top and bottom, the area of the top opening being less than one-half the area of the bottom one. A boss is provided above

this cylinder, joined to it by three or more ribs, to form a guide working on the spindle at the top of the seat. The ribs should be put at such an angle, that the influx of water causes the valve to slightly rotate every time it rises and falls.

It is necessary to be particular in the measurements of the areas of the two seats, for the calculations relating to the suction and delivery valves. The diameters should be measured thus:—Take the *inside* diameter of the *lower* seat, and the *outside* diameter of the *upper* seat to determine the area upon which the water acts in opening the valve. If we assume the exterior diameter of the upper seat to be 9 inches, and the interior diameter of the lower seat to be 11 inches, then the difference of area will be:

$$95 \cdot 033 - 63 \cdot 617 = 31 \cdot 416 \text{ square inches,}$$

and this represents the area upon which the water must act in opening the valve.

A valve of such dimensions would weigh about 100 lbs., hence the pressure requisite to open the suction valve would be:

$$\frac{100}{31 \cdot 416} = 3 \text{ lbs. per square inch.}$$

In this calculation no allowance has been made for the reduction of pressure requisite to open the valve due to the fact of its immersion in water; this reduction would amount to about one-seventh of the weight. In the case of the upper valve there is, of course, the weight of the column of water upon the valve to be overcome in opening it in addition to its own weight.

The column of water thus acting upon the delivery valve is annular, having a base bounded by two circles,

the smaller being equal to the diameter of the *inside* edge of the top beat, and the larger circle being equal to the *outer* edge of the bottom beat. When the valve is open, this last element may be regarded as not acting upon it, as it will with the rest of the water be flowing away, driven by the stream issuing from the pump.

The amount of work actually done in opening the valve is, of course, equal to its specific weight multiplied by the distance through which it is raised.

Taking the weight of each valve as 100 lbs. and its lift 2 inches, we find the amount of work done throughout the stroke for each valve thus:—Obtain the specific weight of each valve by subtracting from it one-seventh of its weight:

$$\frac{100}{7} = 14{\cdot}28\text{; then } 100 - 14{\cdot}28 = 85{\cdot}72 \text{ lbs.,}$$

the lift of the valve = 2 inches = $\frac{1}{6}$ foot,

hence the work done will be

$$85{\cdot}72 \times \frac{1}{6} = 14{\cdot}286 \text{ foot lbs.}$$

for each valve, and for the two valves at each stroke it will be

$$14{\cdot}286 \times 2 = 28{\cdot}572 \text{ foot lbs.}$$

If we, for example, take the area of the pump plunger to be 1 square foot, the stroke 8 feet, and the ***head of water*** against which the pump is working 100 feet. The quantity of water raised at each stroke of the engine will then be 8 cubic feet; and as 1 cubic foot of water weighs $62\frac{1}{2}$ lbs., the weight of water raised by the engine each stroke will be

$$= 62\tfrac{1}{2} \times 8 = 498 \text{ lbs.;}$$

this load being raised to an average height of 100 feet, the amount of work done equals

$$498 \times 100 = 49{,}800 \text{ lbs. per stroke.}$$

From this amount must be deducted the power absorbed in opening the valves, viz.: 28·572 foot lbs.

$$49{,}800 : 28{\cdot}572 = 100 : 0{\cdot}057 \text{ per cent.}$$

This is to all appearance the work absorbed by the valves; but it is evident that more is lost, because the valve is kept open during a period equal to the time occupied by the up-stroke of the plunger by means of the water passing through it; and although it may be chiefly in the form of friction, yet the work is lost, and does not appear in the useful effect.

Allowing for the reduced weight of valve due to its immersion, it is found that the pressure required to keep it suspended is $3 - \frac{3}{7} = 2{\cdot}572$ lbs. per square inch, which represents the difference between the pressure above and below either valve, when open, and which must of course act over the whole area of the pump plunger.

The pressure due to a column of water of 100 feet in height

$$= 100 \times 0{\cdot}433 = 43{\cdot}3 \text{ lbs. pressure per square inch,}$$

and the percentage of pressure added to this will be

$$43{\cdot}4 : 2{\cdot}572 = 100 : 5{\cdot}9 \text{ per cent.,}$$

or nearly 6 per cent. of the work done by the engine.

Let us now compare this loss with that of an ordinary clack delivery valve of the Butterfly type, 20 inches in diameter, the extreme opening of each clack being 6 inches, and the height of delivery column 100 feet, above the

valve, then the pressure of water will be

$$= 0{\cdot}433 \times 100 = 43{\cdot}3 \text{ lbs. per square inch,}$$

the area of each clack will be

$$= \frac{20 \times 20}{2} \times 0{\cdot}7854 = 157 \text{ square inches,}$$

hence the total pressure exerted by the water on each clack will be

$$= 43{\cdot}3 \times 157 = 6798{\cdot}1 \text{ lbs.}$$

Assuming the valve-clack to weigh 300 lbs., the total weight in action on each clack will be

$$= 6798{\cdot}1 + 300 = 7098{\cdot}1 \text{ lbs.}$$

The work done by the descent of this weight will be equal to its intensity (7098·1), multiplied by its mean distance of fall in feet, which must be calculated from the centre of gravity of the semicircular clack. The centre of gravity of a semicircle is nearly 0·425 of the radius distant from the diameter bounding the semicircle; hence, in the present case, the space passed through by each part of the clack being proportional to its distance from the diameter, and the extreme space being assumed at half a foot, the work done on each clack will be

$$= 7098{\cdot}1 \times 0{\cdot}5 \times \frac{10 \times 0{\cdot}425}{10} = 1508{\cdot}34 \text{ lbs.,}$$

and the total work expended on the valve seating due to the action of the two clacks will be

$$= 1508{\cdot}34 \times 2 = 3016{\cdot}68 \text{ foot lbs.}$$

The advantages of this valve are its diminished rise, which reduces the concussion, also its lower percentage of *"slip."* It has, however, the objection, when it beats on

hard faces, that from the circumstance of the two faces being inseparably connected, any dirt, grit, or foreign matter getting between either of the beats will cause considerable leakage in both.

In all valves of this kind the ribs at the top of the shell or the valve itself should be inclined a little from the perpendicular, so that the water in passing through the openings may impart to it a gradual circular motion, which tends to keep the beat perfect, and prevent the formation of grooves.

There are many variations of this class of valves, but the difference is so slight that it is not necessary to illustrate or describe them in this little work.

A valve of the multiple beat description is shown in Fig. 31, Plate VI. It has three beats, and consists of a seat securely fixed in the bottom of the valve-box or clack-seat; in the centre of this seat is formed a boss, into which is fixed a centre-spindle, upon which works three separate valves of the annular type, the bottom one beating on its seat, the top side forming a beat for the second one, and so on, the top valve is furnished with a boss having a covered top to prevent leakage through the same.

It is evident that a valve of the ordinary construction must be lifted from its seat three times as high as this valve in order to allow the passage of the same quantity of water, in the same time, and under the same pressure; because in the rising of this valve each portion opens separately, and consequently has to lift but one-third of the total height; also from the fact of there being a ring of water between each part, they will shut uniformly together until the lower part reaches its seat, when it becomes a seat for the next, and so on progressively, reducing the concussion in proportion to the number of

parts or divisions in the valve; and according to the law of accelerated motion each part will sustain a shock equal to the square root of the height it is raised plus the superficial area of each part.

In this valve, each beat being separate from the other, there is not so much danger of the valve hanging by dirt or grit, for if one beat fails the other beats will act, consequently the amount of leakage will be greatly reduced.

Indiarubber Valves.

The most common indiarubber disc valve is illustrated in Fig. 32, Plate VI. It consists of a gun-metal seat or grid, fixed firmly in the valve-box or bucket, this grid is furnished with a centre-spindle, which in small valves is cast in one with the valve-seat, but in larger ones a separate bolt or stud takes its place; the indiarubber disc is large enough to cover the holes or perforations in the grid, and leaving a lap of from $\frac{1}{4}$ of an inch to $\frac{1}{2}$ an inch, according to the diameter of the valve. On the top of the centre-spindle is fixed a guard for the indiarubber to work against. The centre hole in the indiarubber disc should be about $\frac{1}{8}$th of an inch larger in diameter than the centre-spindle, and the distance between the top of the grid and the under side of the guard should be about $\frac{1}{8}$th of an inch greater than the thickness of the indiarubber disc, to allow the disc to rise before it commences to bend round the guard.

The rotating indiarubber disc valve is shown in Fig. 33, Plate VI. The only difference between this valve and the ordinary one is that the bars in the grating or grid are put at an angle, and by that means the water passing through it produces a circular motion to the disc, prolonging the life of the indiarubber and allowing it to

)yed for greater pressure. The Author has seen
:ubber disc valves of this description which, after
ing constantly for upwards of three years against a
ire of 490 feet, were still in a good condition.
indiarubber disc and ring valve combined, is shown
g. 35, Plate VII.; this consists of a grid with a round
ng in the centre, on to this is placed an indiarubber
held to its place by another grid, on the top of which
ced an indiarubber disc and guard of an ordinary
alve, the whole is held firmly together by a centre-
r spindle. It will be seen by referring to the illus-
a that this is a double-beat indiarubber valve, one
n of the fluid passing through the bottom grid and
her through the top one.
nult·ple beat indiarubber ring valve is illustrated
g. 34, Plate VII. It consists of several grids placed
pon the other; the bottom side of the second grid
ig the guard for the bottom one, and the top
ig the seat for the second ring, and so on, the
asting forms only the guard for the top india-
r ring, the whole being held together by a centre

his class there are many different arrangements.

Ball-Valves.

ordinary ball-valve used for boiler feed pumps, is
ated in Figs. 36 and 37, Plate VII.; it consists of a
ietal seat, a gun-metal spherical ball, and a guard
e, the latter forming a guide, which prevents the
etting out of its seat, besides, determines the height
or rise. To tighten the ball it is sometimes made
r, and to deaden the blow on the seat the ball is
d with indiarubber or guttapercha.

The diameter of the ball is found by multiplying diameter of the seat opening by 134 and divide by 1(

Where cold water is being pumped these balls with advantage be made entirely of indiarubber. V with gun-metal balls have been used for air compress

REMARKS ON DESIGNING PUMP-VALVES.

CLACK-VALVES.

All corners against which leather, indiarubber, vulcanised fibre, or canvas works, should be carefully rounded, to prevent any cutting edges.

Great care should be taken in the selection of the leather, when used either for hinges or simply for a valve facing; for hot water containing copper in solution only the very best bend hides should be used. Good leather, being hard in texture, of a light colour, and presenting a shiny appearance when cut with a knife. Inferior hides are dark coloured, approaching a brownish yellow, and are inclined to sponginess. The harder and firmer the leather the better. In cutting out clack leathers the best portion should be reserved for the front of the clack, where the beats wear most. Leather-hinged clacks often give way at the hinge; attention, therefore, to the quality of the leather for that part is necessary.

The clack when open should make an angle of 30 degrees with its seat, and should never be allowed to exceed an angle of 60 degrees upon any consideration.

The width or lap of beat, that is, the part of the valve which rests on the seat, should be $\frac{1}{10}$th of an inch for every inch in diameter of the seat opening; for example, a 10-inch valve should be 12 inches in diameter, having a lap all round of 1 inch.

The clack should be allowed to lift perpendicular from its face or seat before it commences turning on its centre or pin.

Mitre-Valves.

The angle of the mitre or bevel of the edge of the valve is usually made at an angle of 45 degrees, for it has been found that if the angle be greater the valve has a tendency to *set* in its seat, and if less, an unnecessary space is given to the valve, and a greater pressure will be required to open the valve when closed. When these valves are used in air compressors the angle is sometimes made 60 degrees.

The width of the beat should never be made more than $\frac{1}{4}$ of an inch for the largest size, and for small sizes $\frac{1}{16}$ of an inch is sufficient.

The diameter of the top plate of the valve should never be made larger than the largest diameter of the mitre in the seat.

If the valve is provided with a spindle on the top or bottom, the valve should always be cast with the spindle downwards, to ensure the casting being sound.

Great care should be exercised when designing metal valves of any description to have uniformity of thickness throughout it, and if any inequality is necessary, it should be made gradually, so that there will be no danger of drawing when the casting is cooling.

The lift of these valves should always be made as little as possible, to reduce the banging or hammering of them against their seats; in order to give the valve opening the same area as the seat, the valve should lift one-fourth of the seat's diameter, that is, a 4-inch valve should be allowed to lift 1 inch. If the diameter can be increased a less lift can be given; this is a most desirable feature, to increase the diameter of the valve and reduce the lift. The flow of water through the valve opening should not, if possible, exceed a speed of 200 feet per

minute. For heavy lifts the valve ought not to be allowed to lift more than one quarter of an inch.

The size of the valve-box for this class of valves can readily be obtained by adding the area of the outside diameter of the valve-plate to the area of the seat, the sum of these being equal to the area of valve-box required.

Valve Beats.—The valve beats are made of a composition of lead and tin, wood, leather, or guttapercha. Almost every kind of wood has been tried, the best being birch, holly, and lignum vitæ; oak will not do, on account of the tannic acid present. When the beats are of metal, they must both be made of the same metal, or else a galvanic action will take place, which will eat away the most magnetic metal. When loose beats are used they should be fixed in the valve, not in the seat.

Valves with perpendicular lift should have all the ribs and guides a little inclined from the perpendicular, that the water in passing through the waterway may give the valve a gradual circular motion, which tends to keep the beats perfect and prevent the formation of grooves. An inclination of half an inch in 6 inches is enough.

Indiarubber Valves.—The indiarubber disc should fit easy on the spindle, otherwise it has a tendency to break at the centre.

The guard should be of such a size that when the indiarubber strikes against it it cannot bend again round the edges, otherwise the disc will soon break round the periphery. The guard should be made two thicknesses of the rubber, less in the diameter of the disc; thus a disc 10 inches in diameter, $\frac{1}{8}$ an inch thick, requires a guard 9 inches in diameter.

The disc should be allowed to lift on the spindle from $\frac{1}{8}$ inch to $\frac{1}{4}$ inch, according to the diameter of the valve, before it is stopped by the guard.

A good radius for the curvature of the guard, with the before mentioned lift given to the disc, is the diameter of the disc; thus for a 10-inch disc $\frac{1}{4}$ of an inch free lift, the radius of the guard will be 10 inches.

All holes in the guard and grid should be well rounded, sharp corners presented to the indiarubber should be avoided.

For heavy pressures the width of the openings in the grid should be made equal to the thickness of the indiarubber disc, which should be proportioned to the height of the lift, and varies from $\frac{3}{8}$ to 1 inch and upwards in thickness, according to the quality of indiarubber used.

The ordinary indiarubber disc valve will not work economically with a heavier pressure than 250 feet head, but the rotating disc valves have worked for three years under a pressure of 490 feet and even then were in good working condition.

Quality of Indiarubber.—For cold water pure indiarubber is probably the best, but for ordinary pump-valves the indiarubber with a specific gravity half heavier than water is the best, because pure rubber is so light that the discs have to be forced down by the returning pressure of the pump on the suction-valve, and the rising column on the discharge or delivery valve.

Ball-Valves.

The beating surface for ball-valves made of indiarubber, or metal covered with indiarubber or guttapercha, should be very broad, to prevent the indiarubber being cut; if this is attended to and no sharp edges are left on the seat, a good indiarubber ball will wear perfectly even all round.

If the ball is made of gun-metal the beating-surface need not be quite as broad.

The ball-valve will not work well against a heavier pressure than 200 feet head.

Valves used for hot-water pumps should be made one-half larger in diameter than the piston, or instead of one large valve several small ones, with an aggregate area corresponding to the same, in order to obtain a large waterway and a very small lift of valve.

When gritty or muddy water is pumped, there should be a chamber or recess formed in the valve-box round the valve seat, no matter what class of valve, to allow the grit, mud, or other impurity to gravitate into it, keeping the valve seat clear. A sludge-cock should be provided, so that the sediment can be blown-off at intervals.

MATERIALS OF WHICH PUMP-VALVES SHOULD BE MADE, AND CLASS OF VALVES FOR DIFFERENT LIQUIDS.

For *Strong Acids*, a flat piece of wood loaded with lead and guided at the sides, is by far the best; in some cases lead or glass seats with guttapercha discs have been used with advantage.

For *Ammoniacal Liquor*, the cast malleable iron mitre-valve is generally used, and sometimes the mechanically moved piston-valve.

For *Anthracene Oil*, cast malleable iron mitre-valves.

For liquid *Asphalt*, cast malleable clack-valves, or mechanically moved piston-valves.

For *Benzole*, gun-metal mitre valves or gun-metal clack valves.

For *Benzoline*, the gun metal mitre-valve is recommended.

For *Bilge Pumps*, or other ship purposes, where *salt water* has to be pumped, gun-metal valves of the mitre type, or clack-valves of gun-metal, are largely used. Indiarubber ball-valves have also been frequently employed. The best alloy for the gun-metal consists of:—

Copper	88 per cent.
Zinc	2 „
Tin	10 „

For *Breweries*, any class of valve will do, but clacks are very sluggish in their action, consequently allowing a great deal of slip; they should be made of gun-metal.

For *Creosote*, cast malleable iron clacks or mitre-valves.

For *Fire Engines*, almost any type of quick closing valves will do; some makers prefer rectangular clack valves, with indiarubber rings, to ensure a quick closing; others use indiarubber disc valves; and again, one or two firms employ indiarubber ring valves of the "Field" patent type.

For *Gelatinous Fluids*, not containing acid, gun-metal clack valves; but if there is acid present a large proportion of lead should be used in the gun-metal alloy.

For *Glutinous Fluids*. If the fluid is very thick, mechanically moved piston-valves, or clack-valves made of cast iron, or the bell-valve, will be found to answer remarkably well; but if very thin, cast malleable iron mitre-valves will do.

For *Hot Water*, gun-metal mitre valves and specially prepared indiarubber discs, also vulcanised fibre manufactured for that purpose.

For *Hydrochloric Acid*, mitre valves of Hargreave and Robinson's patent white metal, or an alloy consisting of:—

Lead	1 pound
Tin	1 ounce
Antimony	1 ounce, well mixed together.

For *Milk of Lime*, gun-metal clack valves or bell valves.

For *Mines*. The classes of valves mostly used are the Clack and Butterfly valves, on account of cheapness and ease in repairing. The double clack-valve, illustrated in Fig. 20, Plate V., and described on page 24, is very good; but the double-beat valve made of gun-metal with leather beats fixed on the valve (not on the seat), is the best for moderate size pumps; they have been known to work well for twelve months under heads of 600 to 1000 feet in

dirty, gritty water, without new leather beats being required.

For *Naphtha*, cast iron or cast malleable iron mitre-valves.

For *Oil*, gun-metal mitre or clack valves.

For *Paper Pulp*, cast-iron bell valves, cast malleable bell-valves, or wrought or cast malleable clack-valves.

For *Sewage*. The best valves for sewage are the clack-valves; they should be made in groups of several small ones, having a collective area equal to one-and-a-half times the area of the plunger; the valves should be rectangular, from 4 inches by 9 inches to 9 inches by 18 inches. The valves should be made of cast or wrought iron faced with leather or vulcanised fibre. For small sewage pumps the bell-valves answer well.

For *Sugar solution* and *Treacle*, the clack-valves or mechanically moved piston-valves are the best; the clack-valves act best when they are hung at an angle of 70 degrees to the horizontal line; they should be made of gun-metal beating against gun-metal seats.

For *Tan Liquor*, gun-metal bell or clack valves, but the alloy must possess a great portion of lead, on account of the tannic acid present in the oak bark contained in the liquor.

For *Tar*, the best valves are the mechanically moved piston-valves, or the mitre-valve type made of cast malleable iron. The bell-valves have also been found very serviceable for tar.

For ordinary small pumps for raising *Water*, the most appropriate are of the gun-metal mitre type, indiarubber disc valves, and leather clacks. Indiarubber ball valves, loaded in the interior with lead, have been used for elevating water containing sand and grit.

For Waterworks, the best valves for small pumps with

little lift are gun-metal mitre valves with gun-metal beats and seats. For small pumps with heavy lift, gun-metal mitre valves and seats with guttapercha beats. For pumps of a moderate size, Cornish gun-metal double-beat valves with gun-metal seats and beats. For very large pumps, multiple beat valves with wood or white metal beats should be employed.

Pump Buckets.

There are as many varieties of pump buckets as there are different classes of valves; the Author will therefore confine himself to a few of the most commonly used, giving a sample of each class.

Figs. 39 and 40, Plate VII., illustrate an ordinary *hand pump bucket*, packed with a *cup-leather*. It will be seen that it consists of a body casting, forming a boss at the top, into which the bucket-rod is screwed; by means of a ring screwed on the bottom of the body the cup-leather is secure. The valve consists of a piece of leather fixed firmly to the bucket body by means of two screws, and the leather is furnished with a top and bottom plate secured by a centre bolt and nut or rivet, the bolt being the best, as a new leather can be easily put in its place when the old one requires renewing. A stop should always be provided, to prevent the valve rising too high; this can be done by allowing the bucket-rod to protrude sufficiently below the boss, into which it is screwed, or by making the projection on the under side of the boss, as illustrated.

Figs. 41 and 42, Plate VIII., are illustrations of a bucket fitted with butterfly clacks. The arrangement of the clacks is identical with those in the valve (Figs. 20, 21, and 22, Plate V.). This bucket is made of brass, and the lids faced *with leather*, the hole in the bucket-rod, through

which the hinge-pin passes, is slightly oblong, to allow the clacks to lift perpendicular in opening; the pin is secured endways by a cotter; but should the cotter by any means slip out of its place, the hinge-pin cannot get out so long as the bucket is in the working-barrel. The top part of the bucket is made large enough to fit the working-barrel. The hoop at the bottom of the bucket is also turned to fit the working-barrel. The leather is placed on the bucket in the usual manner, and covered by the hoop below; by this means the leather is prevented from wearing on one side of the bucket, as sometimes occurs, and the leather acting solely as the water-tight joint between the flange on the top and the hoop on the bottom of the bucket. The bottom ring is kept in its place by a cross-piece and cotter.

The ordinary *clack bucket*, as used in the Cornish pumps, is shown in Figs. 43 and 44, Plate VIII. It consists of a bucket-shell or body, usually made of cast iron, but of brass when acidulated water is being pumped; the outside of this shell is covered with a leather ring, and the bottom part of this ring is surrounded by a wrought-iron ring, held in its place by a cross-bar and cotters; through the former passes the fork end of the pump-rod, which is held to the bucket by the same cotters. The valve is of the ordinary clack type, made to lift freely in the guides before it is allowed to turn on its pins.

A bucket fitted with *Indiarubber disc valve* is depicted in Fig. 45, Plate VIII., the packing rings in this case being made of gun-metal, forced against the face of the working barrel by means of a spiral spring. The grid or grating, the bucket-shell and the valve-guard, are all held firmly together between a fixed collar on the top side of the bucket-rod, and a nut and cotter at the bottom.

A bucket fitted with *hemp packing* is shown in Fig. 38,

Plate VII.; it consists of a bucket-shell secured on the bucket-rod by means of two nuts; the valve is of the conical perpendicular lift type, guided by the bucket-rod, which latter is enlarged at that place, and a fixed collar on the rod determines the lift of the valve. A ring fitting the top part of the bucket-shell is furnished with three legs, joined at the top by a boss bored to fit the bucket-rod. The packing consists of hemp plaits, dipped in tallow prior to its being plaited; the hemp plaits are carefully twisted round the bucket-shell and pressed together between the ring and the collar provided round the bottom of the shell by means of the nut above the boss of the ring.

REMARKS ON PUMP BUCKETS.

The buckets should always be made of the same material as the pump valves.

The bucket valves should always, if possible, be of the same type as the suction and delivery valves.

The cup-leathers should be most carefully made of the very best leather that can be procured; this will be found to prove the cheapest in the end.

The same remarks on the leathers for the valves, on page 37, also apply to the bucket leathers and valves.

PUMP PISTONS.

The most common pump piston is illustrated in Fig. 46, Plate VIII. It consists of two cast-iron or gun-metal plates, turned all over, and bored at the centre to fit the pump-rod; another plate of gun-metal, turned all over and bored out to fit the piston-rod in small pumps, but in large ones it is bored to fit a boss or nipple on the inside of the two outside piston-plates; between these two plates is fixed the *cup leathers;* the outside plates must be carefully rounded at the corners, which fit against the cup leathers, and the centre plate must also be turned to accurately fit the outside corners of the leathers, this prevents them altering their shape at each reciprocating motion of the pump piston. The leather of which the cups are made should be selected from the very best English oak-bark-tanned bend hides, and carefully pressed in a mould. For description of the process of making the cup-leathers, see page 52.

A very good packing for pump-pistons raising gritty and dirty water is illustrated in Fig. 47, Plate VIII. It consists of two piston-plates of cast iron, between which are fixed rings made of the best bend leather hippopotamus hide. The leather rings are put in their places, the piston fixed on the rod, and the nut tightened up, afterwards the whole is put in a lathe, and the leather turned perfectly true. This packing wears better than any other in gritty water, and is in daily use in many collieries.

Another type of pump-bucket is illustrated in Fig. 48, Plate IX. It consists of two piston-plates, turned in the groove for *metallic packing rings*, instead of leather packing, and bored out to fit the pump-rod. In this and all the other types of pump-pistons the rod is usually reduced in diameter on that part which passes through the piston, and the end beyond the back of the piston is screwed and provided with a nut, which latter is prevented from working loose by a split pin or cotter, passing either through the nut or just behind it; in that case the rod is weakened, first by turning it less in diameter, secondly by screwing it for the nut; again, it forms of necessity, a very small shoulder, which, if the piston is the least slack on the rod, soon works itself into the piston, and causes a leakage. The best way of securing the piston on the rod is that shown in Fig. 46, Plate VIII., which consists of two nuts; the piston-rod is screwed up, and one nut screwed on tight and secured by a split pin driven through the nut; the piston-plates are next put on to the rod, and then the second nut is screwed on, and prevented from getting loose by a taper-split cotter, the cotter hole being made long enough for tightening in case of wear. This style of fastening the piston on the rod has the double advantage of forming a large shoulder, and only weakening the rod by screwing it for the nut. The packing rings are made

in different ways. The simplest form is shown in Fig. 48, Plate IX. They consist of two cast-iron or gun-metal rings (according to the class of liquid to be pumped) turned a little larger in diameter than the bore of the pump-barrel, and cut across at an angle of 45 degrees.

A more complicated and expensive class of packing is illustrated in Fig. 45, Plate VIII. It consists of two rings of gun-metal; these rings put together form a channel, into which is put another ring cut into a spiral, this latter ring presses the two outer rings laterally, and by that means make a tight joint between the piston-plates and the outer rings. The two outer rings are made larger in diameter than the bore of the barrel, and are cut across at an angle of 45 degrees; there should be in both cases a small peg fixed in each of the outer piston-plates, so that the cross cuts of the two rings do not come in a line, and to prevent the rings from turning round.

Another good *metallic packing* ring consists of one broad ring only, turned a little larger in diameter than the bore of the working-barrel; it is, in the manner shown in Fig. 49A and B, Plate IX. The opening should be the same as the difference between the circumference of the ring before it is inserted into the working-barrel and the circumference of the working-barrel. The process for making this ring is as follows:—First mark off and drill holes, as indicated by the dotted circles in Fig. 49A, Plate IX.; next saw it along the dotted line, joining the two rows of holes; then file it until it assumes the shape shown in full lines in Fig. 49B, Plate IX.

All these types of metallic packing rings must be turned all over and carefully fitted into the recesses in the pistons. The separate plates of the pistons are held together by the nut on the piston-rod in small pumps, but the large pump

pistons are fitted with junk rings, like ordinary steam-pistons.

The simplest pump-piston is illustrated in Fig. 51, Plate IX. It consists of a plain cylinder, turned all over, bored and fitted to the piston-rod; a series of recesses or grooves are next cut round the circumference. This piston acts very well for small quick-running pumps; the leakage is very little, because the loss of energy of motion of the fluid at each sudden enlargement of the annular spaces is very great, and therefore does not give the liquid time to pass between the piston and the circumference of the pump-barrel.

The last type of piston necessary to mention in this little work is shown in Fig. 50, Plate IX. It consists of two castings, turned and fitted, and bored accurately to fit the pump-rod. It will be seen that there is a groove formed between the two castings, into which is carefully twisted plaited hemp steeped in tallow. The packing is tightened up by the nut on the piston-rod. There must be two holes drilled and tapped into the back piston-plate to facilitate the removal of it, two hand screws can be inserted for the purpose when the piston requires to be repacked.

In some designs for this class of packing the piston consists simply of one casting turned with a simple groove round the circumference, without any means of adjustment.

CUP-LEATHERS.

The simplest form of mould for making cup-leathers is illustrated in Figs. 52 and 53, Plate IX.

In making the cup-leathers, the grain of the leather, that is, the outside of the hide, must be the working side. The leather should be carefully selected from the very best bark-tanned hides, the most suitable portion being the hard part of the butt for large leathers, and the shoulders for small leathers. The soft inner portion must be removed with great care by a sharp knife or a plane. Cut out a circle the size required for the leather and a hole in the centre to fit the bolt (this bolt forming the guide for the leather), then the piece must be carefully gauged, and if it is not equal thickness all over it must be planed until it is. When an even thickness is obtained the leather must be steeped in soft water until it is soft and flexible. While in this condition place the leather on the top of the collar, the die on the top of the leather, and the centre-bolt through the whole; then tighten the nut very gradually, until the top die is screwed down to the bottom. The mould must then be left to allow the leather to become thoroughly set. Then fix the leather in a lathe and by means of a shape-chisel or leather-knife cut it level, and bevel off the inside edge. When completed it should be well greased with tallow to keep it moist and ready for use.

AIR-VESSELS.

ə purpose of the *air-vessel* is to correct the intermit-
lischarge of the water into a continuous one, in order
›vent the concussion to the machinery caused by the
required to overcome the inertia of the water, and
onomise the power of the engine by keeping the
in constant motion, thereby increasing the delivery
ter when the pump-pipes are smaller than the pump-
l. By the use of the air-vessel small delivery pipes
ly fixed may be retained when larger pumps or
ng-barrels are required. Where the lift is high and
elivery pipe large, as is the case of large pit pumps
nes, there is no necessity for air-vessels.

r size of air-vessel required for different classes of
s, see Rules and Formulas, page 62.

ere are three distinct classes of air-vessels: one con-
of a large cylinder contracted at each end to the
›ter of the rising main or delivery pipe, and having
ə inserted for the delivery of the water. This pipe
›ught nearly to the bottom of the chamber, leaving
nular space for compressing the air in; this pipe is
l the *dip pipe.* This class of air-vessel is not very
because the air rising in the most direct way allows
little of it to rise into the annular space.

e second class consists of a large pipe with a semi-
lar or hemispherical top; the bottom is closed and
ded with one inlet and one outlet branch.

e third consists of a large pipe with hemispherical
›rovided with a branch at the bottom and another on
ide.

The air-vessels are generally made completely of cast-iron. Sometimes a cast-iron base is used and the vessel proper made of wrought-iron and steel plates, riveted or welded together in the seams.

In large air-vessels an arrangement should be made for charging it with air when the pump is working. In that case the air-vessel is divided into two parts longitudinally by a diaphragm. The bottom part is furnished with a blow-off cock. A pipe fitted with a wheel-valve if furnished, putting the bottom part of the top chamber in communication with the bottom part of the bottom chamber. Another pipe forms a connection between the top part of the upper chamber and the top part of the lower chamber. This latter pipe is furnished with a wheel-valve for closing the communication between the two chambers, and below the valve is fixed, in the same pipe, a small valve communicating with the open air.

The operation for charging the vessel with air is as follows :—

Open the small valve communicating with the open air and the blow-off cock at the bottom chamber, to empty it of water and fill it with air.

Close the air and blow-off cock.

Open the valve which is fitted in the pipe communicating between the bottom of the top chamber and the bottom of the lower chamber, which causes the water to enter the bottom chamber from the top one.

Then open the valve on the pipe communicating between the top of the top chamber and the top of the lower chamber; this allows the air in the lower chamber to rise into the top of the upper chamber. This being effected, close all the valves.

Should this not supply sufficient air, the process should *be repeated.*

A *manhole* is sometimes provided in large air-vessels for cleaning out mud and other sediment.

A *snifting valve* should be provided on the highest part of the air-vessel, for replacing the air which has been absorbed by the water.

A *glass water-gauge* should be provided to indicate the height of the water in the air-vessel.

RULES AND FORMULAS.

To find the Load on a Pump:—

Rule.—Multiply the area of pump in inches by the weight of the column of water in pounds per square inch.

Example.—Pump 3 inches in diameter; depth of well 30 feet:—

3 inches diameter = 7·06 inches area,

$\frac{30 \times 44}{100}$ = 13·2 lbs. pressure per square inch,

7·06 × 13 = 91·78 lbs. total pressure on pump.

To find the Force required to work the Lever of a Hand-pump:—

The leverage of a pump-handle is usually 6 to 1.

Rule.—Multiply the area of pump in inches by the weight of the column of water in pounds per square inch, this divided by the leverage of the lever equals the force required in pounds.

Example.—Pump 3 inches in diameter; depth of well 30 feet; leverage of handle 6 to 1:—

3 inches diameter of pump = 7·06 inches area,

30 feet = 13 lbs. pressure per square inch,

$\frac{7 \cdot 06 \times 13}{6}$ = 15·29 = 15¼ lbs. full.

To find the Force necessary to work the handle of a Pump actuated by crank and handle:—

Rule.—Multiply the area of the pump in inches by the weight of the column of water to be lifted in pounds per

square inch, this divided by radius of handle divided by the throw of pump equals the force required in pounds.

The handle is usually 15 to 16 inches centres.

Example.—Pump 4 inches diameter; stroke of pump 8 inches; radius of handle 16 inches; depth of well 40 feet:

4 inches diameter = 12·56 inches area,

40 feet head = 17·3 lbs. pressure,

12·56 × 17·3 = 217·28 lbs. total pressure,

8 inches stroke = 4 inches throw of crank,

$\frac{16}{4}$ = 4 times leverage,

$\frac{217 \cdot 28}{4}$ = 54·3, say 54½ lbs.

To find the Force necessary to work the handle of a Pump actuated by crank gearing and handle:—

Rule.—Multiply the area of a pump in inches by the weight of the column of water in pounds per square inch, the result divided by the radius of handle, divided by the throw of crank multiplied by the proportion of gearing, equals the force required in pounds.

Example.—Pump 4 inches in diameter; depth of well 40 feet; stroke of pump 8 inches; handle 16 inches centres:

4 inches diameter = 12·56 inches area,

40 feet head = 17·3 lbs. pressure per square inch,

12·56 × 17·3 = 217·28 lbs. total pressure,

8 inch stroke = 4 inches throw of crank.

Gearing 2 to 1.

$\frac{16}{4}$ = 4 times leverage of handles and crank, 2 to 1 gearing multiplied by 4 times leverage equals 8.

$\frac{217 \cdot 28}{8}$ = 27·1, say 27 lbs. force required.

A man turning a handle of a well frame will exert with *comfort 20 lbs.*

To find the Quantity of Water in gallons per minute delivered by a pump:—

Rule.—Multiply the diameter of pump in inches by itself and by 34, then by the piston speed of the bucket or plunger in feet per minute, and divide the result by 1000.

Example.—4 inches diameter of pump; bucket speed 100 feet per minute:—

$$\frac{4 \times 4 \times 34 \times 100}{1000} = 54{\cdot}4 = \text{nearly } 54\tfrac{1}{2} \text{ gallons per minute.}$$

If the pump is *single-acting* the result has to be divided by 2.

$$\frac{54\frac{1}{2}}{2} = 27\tfrac{1}{4} \text{ gallons per minute.}$$

If the pump is *treble-barrel* one-half of the result must be added:

$$54\tfrac{1}{2} + 27\tfrac{1}{4} = 81\tfrac{3}{4} \text{ gallons per minute.}$$

If the pump is of the *bucket and plunger*, or piston and plunger type, it must be taken as a double-acting pump, and the diameter taken must be the diameter of plunger, not the bucket or piston.

To find the diameter of the Pump, when the quantity of gallons required and the bucket speed are given:—

Rule.—Multiply the bucket speed in feet per minute by 34, and divide the result into the number of gallons to be raised per minute multiplied by 1000, and the square root extracted out of the product will give the diameter of pump required in inches.

Example.—Required to raise 85 gallons of water per minute, at a bucket speed of 100 feet per minute:—

$$\sqrt{\frac{85 \times 1000}{34 \times 100}} = \sqrt{25} = 5 \text{ inches diameter of pump required.}$$

Approximate rule for quantity of water delivered by Pumps:—

Rule.—Multiply the diameter of the pump in inches by itself and by twice the bucket speed in feet per minute, the product will be approximately the quantity of water delivered by the pump per hour.

Example.—Pump 4 inches in diameter, run at a piston speed of 100 feet per minute :—

$$4 \times 4 \times 2 \times 100 = 3200 \text{ gallons per hour.}$$

There is no account taken of *loss by leakage* or "*slip*," nor *friction* in any of these rules; these vary greatly according to the class and condition of pump, if it is working against a high or low lift and the "slip" depending upon the class of valve used for the pump.

For well designed direct-acting horizontal pumps, one-tenth should be enough for "*slip*," for ordinary purposes, and 25 per cent. for *friction*, but when the suction is very long and the height to where the water is raised is great, one-third should be added; but if the pump is old and badly designed, as much as one-half must be added to the total amount required.

In an ordinary direct-acting steam pump one-fourth of the power required should be added, but if the delivery height is very great and the pipe very long one-half should be added.

To find the number of Horse-power required to raise a given quantity of Water in gallons to a given height in feet:—

Rule.—Multiply the given number of gallons of water to be raised per minute by 10 (which is the weight of one gallon) and by the height the water has to be raised in feet, and divide the product by 33,000.

Example.—100 gallons of water per minute to a h of 200 feet:—

$$\frac{100 \times 10 \times 200}{33000} = 6 \text{ horse-power.}$$

Note.—One-quarter to one-half should be added friction.

To find the number of Horse-power required to raise a quantity of Water in gallons to a given height in yards:—

Rule.—Multiply the given number of gallons of w to be raised per minute by 10 and by the height the w has to be raised in yards, and divide the produc 11,000.

Example.—100 gallons of water per minute to a he of 100 yards:—

$$\frac{100 \times 10 \times 100}{11000} = 9 \text{ horse-power.}$$

To find the number of Horse-power required to raise a quantity of Water in gallons to a given height in fathoms:

Rule.—Multiply the given number of gallons of w to be raised per minute by 10 and by the height the w has to be raised in fathoms, and divide the product 5500.

Example.—100 gallons of water per minute to a he of 100 fathoms:—

$$\frac{100 \times 10 \times 100}{5500} = 18 \text{ horse-power.}$$

To find the diameter of Cylinder required for a direct-a steam pump:—

Rule.—Mulptiply the area of pump-bucket or ran inches by the pressure of water in pounds per squ inch, and divide the product by the pressure of steam

pounds per square inch, and add one-fourth to one-half for friction.

Example.—6 inches diameter of pump, 100 lbs. water pressure per square inch, 50 lbs. steam pressure:—

6 inches diameter = 28·27 inches area,

$\frac{28{\cdot}27 \times 100}{50} = 56{\cdot}54$ inches, area of steam-cylinder,

add $\frac{1}{4} = 56{\cdot}54 + 14{\cdot}13 = 70{\cdot}67 = 9\frac{1}{2}$ inches diameter of steam-cylinder, nearly.

To find the steam pressure required when the diameter of steam-cylinder, diameter of pump-cylinder, and water pressure are given:—

Rule.—Multiply the area of the pump in inches by the pressure of water in pounds per square inch, and divide the product by the area of cylinder, plus one-fourth for friction.

Example.—6 inches diameter of pump-cylinder, 100 lbs. water pressure per square inch, 70·88 inches area of steam-cylinder:—

$\frac{28{\cdot}27 \times 100}{70{\cdot}88} = 39.8 + \frac{1}{4} = 49{\cdot}7$, nearly 50 lbs. pressure per square inch.

To find the thickness required for cast-iron pipes when the pressure is given in pounds per square inch:—

Rule.—Multiply the diameter of the pipe in inches by the pressure of water in pounds per square inch, and divide the product by 2000 or 3000, according to the quality of the iron.

Example.—10 inches diameter of pipe, pressure of water 346 lbs. per square inch:—

$$\frac{346 \times 10}{2000} = 1{\cdot}73; \text{ or } \frac{346 \times 10}{3000} = 1{\cdot}12.$$

Suction and Delivery Pipes.

The *suction-pipe* should be larger than the *delivery pipe* because *friction* is overcome in the *suction-pipe* by the atmospheric pressure only. In direct-acting steam pumps the *suction-pipe* is usually made about one-half of the area of the working-barrel, but if the pump is quick-running required for raising thick liquids, or is very long, it ought to be made larger; in fact, in some cases they are made the same diameter as the working-barrel. In large Cornish plunger pumps the *suction-pipe* should be made large, as the suction-stroke is very quick, the rods being lifted by steam, and the water being forced up by the weight of the rods is rather slow.

The *delivery pipes* are usually made one-third of the diameter of the working-barrel, but if the pump is quick-running or the pipe very long, they should be made half the area of the working-barrel. A good speed for the water in pump-pipes is 200 feet per minute, but it should never exceed 400 feet per minute.

Vacuum Vessel.

If the suction-pipe is very long the vacuum vessel should be placed on it, as near the pump as convenient the air in it becomes expanded, and its elastic force causes the water to flow uniformly into the pump-barrel, and ensures it being properly filled at each stroke. The vacuum vessel should be at least twice the capacity of the pump-cylinder.

Air-Vessel.

An *air-vessel* should always be provided for heavy pressures or long delivery pipes. For ordinary pumps it should be three to four times the capacity of each stroke

of the pump, but for very heavy pressures and fire-engines it should be double that capacity.

The *position* of the *air-vessel* should be so chosen that the absorbed air can be replaced by the pump.

The *neck* of the *air-vessel* and *vacuum vessel* should be long and narrow, to prevent the water level in it being disturbed by the action of the pump.

Speed of Pumps.

The speed of pumps varies according to circumstances and the class of liquid pumped.

Ordinary direct-acting steam pumps run at from 100 to 120 feet per minute.

Single, *double*, and *treble-barrel pumps* from 45 to 80 feet per minute.

Large pumps for *mines* run at an average speed of 130 feet per minute.

The *best speed* for large *pumping engines* is obtained by multiplying the square root of the length of stroke of the pump by 80.

Size of Pump-Valves.

The pump-valves should be so much larger than the pipes, as to give a clear waterway the same area as the pipes.

Lift of the Valves.

The lift should be as little as possible without causing too much frictional resistance to the water; in any case the speed of the water through the suction-valve should not exceed 300 feet per minute.

To find the weight of cast-iron pipes approximately :—

Rule.—For a pipe, 9 feet long, and 1 inch thick, with a flange at each end, allow 1 cwt. for every inch of the

diameter, keeping the thickness and weight proportional either more or less.

Examples.—A 12-inch pipe, 9 feet long, flange at each end, 1 inch thick, will weigh approximately 12 cwt:—

A 12-inch pipe, 9 feet long, flange at each end, $\frac{3}{4}$ inch thick, equals 9 cwt.

A 10-inch pipe, 9 feet long, flange at each end, $\frac{1}{2}$ inch thick, equals 5 cwt.

HYDRAULIC MEMORANDA.

Weight of a cubic foot of water equals 62½ lbs.

Weight of a cylindrical foot of water equals 49 lbs.

Weight of 1 ***gallon of water*** equals 10 lbs.

One ton of water equals 36 cubic feet, nearly.

One gallon of water equals 277¼ cubic inches, full.

Pressure in lbs. per square inch equals the head of water in feet multiplied by 434, and divided by 1000, or practically ·44.

Head of water in feet equals pressure in lbs. per square inch multiplied by 2307, and divided by 1000, or practically 2·3.

For Waterworks.

Allow 15 to 20 gallons of water per head of population per day in non-manufacturing towns.

20 to 30 gallons per head in manufacturing towns.

Maximum demand 2½ times the average.

The mains should be large enough for double the average supply.

Work done by Men and Animals.

Labourer turning a handle.—In working daily at a pump-handle, the average force is 14 lbs., moving at a rate of 220 feet per minute, equivalent to 3080 foot pounds per minute. 25 lbs. at the handle for short periods; but for continuous work a force of 15 lbs., moving through 220 feet per minute.

A labourer can turn the crank-handle from 25 to 30

times per minute, for a continuance, exerting a pressure of 20 lbs. at the handle; or he can apply a pressure of 28 to 30 lbs. for a short time, or from 50 to 56 lbs. at an emergency.

Labour of Horses.

Horses Raising Water.—23,412 foot pounds per minute for 8 hours a-day. 24,360 foot pounds per minute for 6 hours a-day. 27,056 foot pounds per minute for 4½ hours a-day. 32,943 foot pounds per minute for 3 hours a-day.

A Mule working 8 hours will raise 10,000 foot pounds per minute.

An Ass working 8 hours will raise 3500 foot pounds per minute.

A pair of *well-fed Indian Bullocks* will raise 82 bags of water, 22 feet high in one hour, for a morning's work of 4½ hours. Each bag contains 4½ cubic feet of water, and the work is equivalent to 8000 foot pounds per minute.

The speed of an *Indian Bullock* is 2 miles per hour.

Length of a *Bullock walk* is 62 feet.

Modulus of Pumps.

Common lift pumps	equal	·60
Pumps for drainage	„	·60
Fire engines	„	·57
Pumps for mines and deep wells	„	·66 to ·76
Three-throw pumps	„	·76
Waterworks pumps	„	·80 to ·90
Small centrifugal pumps	„	·25
Medium size centrifugal pumps for low lifts	„	·50
Large centrifugal pumps	„	·60

TABLES.

TABLE I.

QUANTITY OF WATER DISCHARGED PER MINUTE BY SINGLE-BARREL PUMPS, from 2 to 6-inch Diameter, at 30 and 40 Strokes per minute, 9, 10 and 12-inch Stroke.

Diameter of Pump.	9-Inch Stroke. Gallons per Minute.		10-Inch Stroke. Gallons per Minute.		12-Inch Stroke. Gallons per Minute.	
	30 Strokes.	40 Strokes.	30 Strokes.	40 Strokes.	30 Strokes.	40 Strokes.
in.						
2	3·0	4·0	3·33	4·44	4·0	5·3
2½	4·6	6·25	5·21	6·94	6·25	8·33
3	6·7	8·93	7·44	9·92	8·93	11·9
3½	8·83	12·2	9·81	13·55	11·77	16·26
4	11·96	15·9	13·28	17·66	15·94	21·2
4½	15·2	20·3	16·88	22·55	20·26	27·6
5	18·75	25·0	20·83	27·77	25·0	33·33
5½	22·69	30·25	25·21	33·5	30·25	40·33
6	27·0	36·0	30·0	40·0	36·0	48·0

TABLE II.

QUANTITY OF WATER DISCHARGED PER MINUTE BY DOUBLE-BARREL PUMPS, from 2 to 6-inch Diameter, at 30 and 40 Strokes per Minute, 9, 10 and 12-inch Stroke.

Diameter of Pump.	9-Inch Stroke. Gallons per Minute.		10-Inch Stroke. Gallons per Minute.		12-Inch Stroke. Gallons per Minute.	
	30 Strokes.	40 Strokes.	30 Strokes.	40 Strokes.	30 Strokes.	40 Strokes.
in.						
2	6·0	8·0	6·66	8·88	8·0	10·6
2½	9·38	12·5	10·42	13·88	12·5	16·66
3	13·4	17·86	14·88	19·84	17·86	23·8
3½	17·66	24·4	19·62	27·10	23·54	32·52
4	23·92	31·8	26·56	35·32	31·88	42·4
4½	30·4	40·6	33·76	45·1	40·52	54·12
5	37·5	50·0	41·66	55·54	50·0	66·66
5½	45·38	60·5	50·42	67·0	60·5	80·66
6	54·0	72·0	60·0	80·0	72·0	96·0

TABLE III.

QUANTITY OF WATER DISCHARGED PER MINUTE BY TREBLE-BARREL PUMPS, from 2 to 6-inch Diameter, at 30 and 40 Strokes per Minute, 9, 10 and 12-inch Stroke.

Diameter of Pump.	9-Inch Stroke. Gallons per Minute.		10-Inch Stroke. Gallons per Minute.		12-Inch Stroke. Gallons per Minute.	
	30 Strokes.	40 Strokes.	30 Strokes.	40 Strokes.	30 Strokes.	40 Strokes.
in.						
2	9·0	12·0	9·99	13·32	12·0	15·6
2½	14·7	18·75	15·63	20·82	18·75	24·99
3	20·1	26·79	22·32	29·79	26·79	35·7
3½	26·49	36·6	29·43	40·65	35·31	48·78
4	35·88	47·7	39·84	52·98	47·82	63·6
4½	45·6	60·9	50·64	67·65	60·78	81·11
5	56·25	75·0	62·49	83·31	75·0	99·99
5½	68·7	90·75	75·63	100·5	90·75	120·99
6	81·0	108·0	90·0	120·0	108·0	144·0

TABLE IV.

Total Pressure in Pumps from 2 to 6-Inch Diameter. Height of Delivery from 10 to 200 Feet.

Height of Delivery.	Diameter of Pumps.								
	2-Inch.	2½-Inch.	3-Inch.	3½-Inch.	4-Inch.	4½-Inch.	5-Inch.	5½-Inch.	6-Inch.
ft.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
10	13·4	21·3	30·6	41·8	54·5	69·1	85·3	102·6	128·8
20	27·3	42·6	61·4	83·6	109·1	138·2	170·6	205·3	245·7
30	40·9	64·0	92·1	125·4	163·8	207·3	256·0	308·0	368·6
40	54·6	85·0	122·8	167·2	218·4	276·5	341·3	410·6	491·0
50	68·2	106·0	153·5	209·0	273·0	345·6	426·6	513·3	614·4
60	81·9	128·0	184·3	250·0	327·6	414·7	512·0	616·0	737·3
70	95·5	149·0	215·0	292·0	382·3	483·8	597·3	718·0	860·1
80	109·2	170·6	245·0	334·5	436·9	553·0	682·6	821·3	983·1
90	122·8	192·0	276·0	376·3	491·5	622·1	768·0	924·0	1106·0
100	136·5	213·3	307·1	418·1	546·1	691·1	853·3	1026·6	1228·8
110	149·9	234·6	337·7	459·9	600·6	760·2	938·6	1129·2	1351·6
120	163·8	255·9	368·5	501·7	655·2	829·3	1023·9	1225·9	1474·5
130	177·4	277·3	399·2	543·5	709·9	898·4	1109·3	1328·6	1597·4
140	191·1	298·6	435·9	585·3	764·5	967·6	1194·6	1431·2	1719·8
150	204·7	319·9	460·6	627·1	819·1	1036·7	1279·7	1533·9	1843·2
160	218·4	341·3	491·4	668·9	873·7	1105·8	1365·3	1642·6	1966·1
170	233·0	362·3	522·1	710·7	928·4	1112·4	1450·5	1745·2	2088·9
180	254·0	283·9	552·8	752·6	983·0	1244·1	1535·9	1847·9	2211·9
190	259·3	405·3	583·6	794·4	1037·6	1313·2	1621·3	1950·6	2334·8
200	273·0	426·6	614·2	836·2	1092·2	1382·2	1706·6	2053·2	2457·6

TABLE V.

PRESSURE OF WATER AT DIFFERENT HEADS IN LBS. PER SQUARE INCH.

Head of Water in Feet.	Head of Water in Yards.	Head of Water in Fathoms.	Head of Water in Metres.	Pressure in Lbs. per Square Inch.	Head of Water in Feet.	Head of Water in Yards.	Head of Water in Fathoms.	Head of Water in Metres.	Pressure in Lbs. per Square Inch.
10	3·33	1·66	3·04	4·33	150	50·0	25·0	45·7	64·9
20	6·66	3·33	6·09	8·66	160	53·3	26·6	48·7	69·3
30	10·0	5·0	9·14	12·9	170	56·6	28·3	51·8	73·6
40	13·3	6·66	12·1	17·3	180	60·0	30·0	54·8	77·9
50	16·6	8·33	15·2	21·6	190	63·3	31·6	57·9	82·3
60	20·0	10·0	18·2	25·9	200	66·6	33·3	60·9	86·6
70	23·3	11·6	21·3	30·3	210	70·0	35·0	64·0	90·9
80	26·6	13·3	24·3	34·6	220	73·3	36·6	67·0	95·3
90	30·0	15·0	27·4	38·9	230	76·6	38·3	70·1	99·6
100	33·3	16·6	30·4	43·3	240	80·0	40·0	73·1	103·9
110	36·6	18·3	33·5	47·6	250	83·3	41·6	76·2	108·3
120	40·0	20·0	36·5	51·9	260	86·6	43·3	79·2	112·6
130	43·3	21·6	39·6	56·3	270	90·0	45·0	82·2	116·9
140	46·6	23·3	42·6	60·6	280	93·3	46·6	85·3	121·3

TABLE VI.

STRENGTH OF PIPES. Safe Working *Pressure in lbs. per* Square Inch. Thickness from $\frac{1}{8}$ inch to 3 inches; diameter from 3 to 36 inches.

Diameter.	Thickness of Pipe in Inches.													
	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{2}$	3
in.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
3	233	466	700	933	1167	1400	1633	1867	2333	2800	3267	3733	4667	5600
4	175	350	525	700	875	1050	1225	1400	1750	2100	2450	2800	3500	4200
5	140	280	420	560	700	840	980	1120	1400	1680	1960	2240	2800	3360
6	116	233	350	466	583	700	817	933	1167	1400	1633	1867	2333	2800
7	100	200	300	400	500	600	700	800	1000	1200	1400	1600	2000	2400
8	87	175	262	350	437	525	612	700	875	1050	1225	1400	1750	2100
9	77	155	233	311	387	466	544	621	777	912	1087	1245	1553	1864
10	70	140	210	280	350	420	490	560	700	840	980	1120	1400	1680
11	63	127	191	255	318	382	446	509	677	764	891	1019	1273	1528
12	58	117	175	233	292	350	408	467	583	700	817	933	1167	1400
15	46	93	140	187	233	280	327	373	467	560	653	747	934	1120
18	39	78	117	156	195	234	273	312	390	468	546	624	780	936
21	33	66	100	133	167	200	233	267	333	400	467	533	667	800
24	29	58	87	116	145	174	203	232	290	348	392	464	580	696
30	23	46	70	93	117	140	163	187	233	280	327	373	467	560
36	19	39	58	78	97	117	136	156	195	234	273	312	390	468

TABLE VII.

WEIGHT OF PUMP-PIPES, FROM 4 TO 24 INCHES DIAMETER; 9 FEET LONG, INCLUDING 2 FLANGES.

Diameter of Pipe.	Thickness.	Weight.	Diameter of Pipe.	Thickness.	Weight.
in.	in.	cwt. qrs. lbs.	in.	in.	cwt. qrs. lbs.
4	$\frac{3}{4}$	3 0 0	15	$1\frac{1}{4}$	18 3 [illegible]
$4\frac{1}{2}$	$\frac{3}{4}$	3 1 14	16	$1\frac{1}{4}$	19 0
5	$\frac{7}{8}$	4 1 14	16	$1\frac{3}{8}$	22 0
6	1	6 0 0	17	$1\frac{1}{4}$	21 0
7	1	7 0 0	17	$1\frac{3}{8}$	23 1
8	1	8 0 0	18	$1\frac{1}{4}$	22 2
9	1	9 0 0	18	$1\frac{3}{8}$	24 3
9	$1\frac{1}{8}$	10 0 0	19	$1\frac{1}{4}$	23 3
10	1	10 0 0	19	$1\frac{3}{8}$	26 0 [illegible]
10	$1\frac{1}{8}$	11 1 0	20	$1\frac{1}{4}$	25 0
11	1	11 0 0	20	$1\frac{1}{2}$	30 0 [illegible]
11	$1\frac{1}{8}$	12 1 14	21	$1\frac{1}{4}$	26 1 [illegible]
12	$1\frac{1}{8}$	13 2 0	21	$1\frac{1}{2}$	31 2 [illegible]
12	$1\frac{1}{4}$	15 0 0	22	$1\frac{1}{4}$	27 2 0
13	$1\frac{1}{8}$	14 2 14	22	$1\frac{1}{2}$	33 0 0
13	$1\frac{1}{4}$	16 1 0	23	$1\frac{1}{4}$	28 0 0
14	$1\frac{1}{8}$	15 3 0	23	$1\frac{1}{2}$	34 2 0
14	$1\frac{1}{4}$	17 2 0	24	$1\frac{1}{4}$	30 0 0
15	$1\frac{1}{8}$	16 3 14	24	$1\frac{1}{2}$	36 0 0

TABLE VIII.

Pipe Flanges and Bends.

Diameter of Pipe.	Pipes.						Bends.	
	Thickness of Pipe.	Diameter of Flange.	Thickness of Flange.	Centre of Holes.	Number of Holes.	Diameter of Bolts.	Length.	Radius.
in.	in.	in.	in.	in.	in.	in.	in.	in.
2	7/16	6	3/4	4 3/4	4	1/2	5	3 1/2
2 1/2	7/16	7	7/8	5 1/4	4	5/8	5 1/2	3 3/4
3	7/16	7 1/2	7/8	5 3/4	4	5/8	5 3/4	4
3 1/2	1/2	8	7/8	6 1/4	4	5/8	6 1/4	4 1/2
4	1/2	9	1	7	4	3/4	6 1/2	4 3/4
5	1/2	10	1	8	4	3/4	7 1/2	5 1/4
6	5/8	11 1/2	1 1/8	9 1/2	6	3/4	8	5 3/4
7	5/8	13	1 1/8	10 3/4	6	7/8	9	6 1/2
8	5/8	14	1 1/4	11 3/4	6	7/8	10	7
9	3/4	14 1/2	1 1/4	12 1/2	8	3/4	10 1/2	7 1/2
10	3/4	15 1/2	1 3/8	13 1/2	8	3/4	11	8
11	3/4	16 1/2	1 3/8	14 1/2	8	3/4	12	8 1/2
12	7/8	18 1/2	1 1/2	16 1/2	8	7/8	13	9
13	7/8	19 1/4	1 1/2	17 1/4	8	7/8	13 1/2	9 1/2
14	7/8	20 3/4	1 5/8	18 1/4	8	7/8	14	10
15	1	22 1/2	1 5/8	19 1/2	8	7/8	15	10 1/2
16	1	23 1/2	1 3/4	20 1/2	10	7/8	16	11
17	1	24 1/2	1 3/4	21 1/2	10	7/8	16 1/2	11 1/2
18	1 1/8	26	1 7/8	23	10	1	17	12
19	1 1/8	27	1 7/8	24	10	1	18	12 1/2
20	1 1/8	28	2	25	10	1	19	13 1/2
21	1 1/4	29	2	26 1/4	10	1 1/8	19 1/2	14

TABLE IX.

Sizes of Buckets and Clacks.

Diameter of Working Barrel.	Buckets and Clacks.				Bucket Shank.		Bucket Hoops.	
	Taper about $\frac{1}{8}$ Inch to 1 Inch.							
	Depth of Shell.		Thickness at Top.	Size of Shank Holes.	Size of Bucket Shank.	Size at Joint of Bucket Shank.	Depth of Bucket Hoops.	Thickness at Bottom of Bucket Hoops.
	Middle.	Sizes.						
in.	in.	in.	in.	ft.	in.	in.	in.	in.
6	3	3	$\frac{3}{8}$	$2\frac{3}{4} \times \frac{3}{8}$	$2 \times 1\frac{1}{4}$	2	1	$\frac{1}{8}$
8	$3\frac{1}{4}$	$3\frac{1}{4}$	$\frac{7}{16}$	$3 \times \frac{7}{16}$	$2\frac{1}{4} \times 1\frac{3}{8}$	$2\frac{1}{4}$	$1\frac{1}{2}$	$\frac{3}{16}$
10	$3\frac{1}{2}$	$3\frac{1}{2}$	$\frac{1}{2}$	$3\frac{1}{4} \times \frac{1}{2}$	$2\frac{1}{4} \times 1\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{1}{2}$	$\frac{1}{4}$
12	$3\frac{3}{4}$	$3\frac{3}{4}$	$\frac{9}{16}$	$3\frac{1}{2} \times \frac{9}{16}$	$2\frac{5}{8} \times 1\frac{3}{4}$	$2\frac{5}{8}$	$1\frac{3}{4}$	$\frac{5}{16}$
14	4	5	$\frac{5}{8}$	$3\frac{3}{4} \times \frac{5}{8}$	$2\frac{3}{4} \times 2$	$2\frac{3}{4}$	2	$\frac{3}{8}$
16	$4\frac{1}{4}$	6	$\frac{3}{4}$	$4 \times \frac{3}{4}$	$3 \times 2\frac{1}{4}$	3	$2\frac{1}{2}$	$\frac{7}{16}$
18	$4\frac{5}{8}$	$6\frac{1}{2}$	$\frac{7}{8}$	$4 \times \frac{3}{4}$	$3\frac{1}{8} \times 2\frac{1}{2}$	$3\frac{1}{8}$	$2\frac{5}{8}$	$\frac{1}{2}$
20	5	$6\frac{3}{4}$	1	$*4\frac{1}{2} \times \frac{13}{16}$	$3\frac{1}{4} \times 2\frac{3}{4}$	$3\frac{1}{4}$	$2\frac{3}{4}$	$\frac{9}{16}$
22	$5\frac{1}{2}$	$7\frac{1}{4}$	$1\frac{1}{8}$	$*4\frac{3}{4} \times \frac{7}{8}$	$3\frac{1}{2} \times 3$	$3\frac{1}{2}$	$2\frac{7}{8}$	$\frac{5}{8}$
24	6	$7\frac{3}{4}$	$1\frac{1}{4}$	$*5 \times 1$	$3\frac{3}{4} \times 3\frac{1}{4}$	$3\frac{3}{4}$	3	$\frac{5}{8}$

Dimensions marked * have two holes below.

TABLE X.

Spears and Bucket Rods.

Diameter of Pumps.	Spears, Square	Spear-plates and Bolts.					Bucket Rods.	
		Length.	Breadth.	Thickness in Middle.	Thickness at Ends.	Diameter of Bolts.	Square	Length of U-plates.
in.	in.	ft.	in.	in.	in.	in.	in.	ft.
6	3	6	$2\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{16}$	$\frac{5}{8}$	$1\frac{1}{2}$	$4\frac{1}{2}$
8	$3\frac{1}{2}$	$6\frac{1}{2}$	$2\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{16}$	$\frac{5}{8}$	$1\frac{3}{4}$	$4\frac{3}{4}$
10	4	7	3	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{4}$	2	5
12	$4\frac{1}{2}$	$7\frac{1}{2}$	$3\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{4}$	$2\frac{1}{4}$	$5\frac{1}{4}$
14	5	8	$3\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{7}{8}$	$2\frac{1}{4}$	$5\frac{1}{2}$
16	$5\frac{1}{2}$	$8\frac{1}{3}$	4	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{7}{8}$	$2\frac{3}{4}$	6
18	6	9	4	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{7}{8}$	3	$6\frac{1}{2}$
20	$6\frac{1}{2}$	$9\frac{1}{2}$	$4\frac{1}{2}$	$\frac{7}{8}$	$\frac{5}{8}$	1	$3\frac{1}{2}$	7
22	7	10	$4\frac{1}{2}$	$\frac{7}{8}$	$\frac{5}{8}$	$1\frac{1}{8}$	$3\frac{1}{2}$	$7\frac{1}{2}$
24	$7\frac{1}{2}$	$10\frac{1}{2}$	$4\frac{3}{4}$	1	$\frac{3}{4}$	$1\frac{1}{4}$	$3\frac{3}{4}$	8

INDEX.

A.

Acid, hydrochloric, 43
" strong, 16
" weak, 17
Action of a pump, 1
Air lodge, 12, 14
" vessel, 53
" " charging apparatus for, 54
" " position of, 63
" " size of, 62
Ammoniacal liquor, 17
Annular ring-valve, 27
Anthracene oil, 17
Approximate quantity delivered by pumps, 59
Approximate weight of cast-iron pipes, 63
Asphalt, 42
Ass, power of an, 66

B.

Ball-valve, 35, 40
", " indiarubber, 40
", " metal, 40
Beats, valve, 39
Beer, pump for, 17
Bell-valve, 27
Benzole, pump for, 17
Benzoline, pump for, 17
Best speed for pumping engines, 63
Bilge pump, 21, 42
Bleaching mills, pump for, 17
Bore-hole pump, 17
Breweries, pump for, 18

Bucket, 45
„ and plunger pump, quantity delivered by, 58
„ „ „ „ vertical, 10
„ „ ram „ quantity delivered by, 58
„ „ „ „ vertical, 10
„ pump for mines, 4
„ „ ordinary, 4
„ rods, table of, 74
„ with butterfly valve, 45
„ „ clack-valve, 46
„ „ cup-leather packing, 45
„ „ hemp packing, 47
„ „ indiarubber disc valve, 46
„ „ metallic packing, 46
„ remarks on designing, 48
Bullock, power of, 66
Butterfly valve, 24

C.

Cast-iron pipes, rules for weight of, 63
„ „ „ table of weight of, 72
„ „ „ bends, table of, 73
„ „ „ flanges, table of, 73
Centrifugal pumps, modulus of, large, 66
„ „ „ „ medium, 66
„ „ „ „ small, 66
Change of direction in the flow of water, 15
Charging apparatus for air-vessels, 54
Clack-valves, 24
„ „ double-beat, 25
Classification of pumps, 3
Common clack-valve, 24
„ lift pump, 4
Conical mitre-valve, 26
Creosote, pump for, 18
Cup-leathers, 52
„ „ press for, 52
Cylinder, diameter required, 60

D.

Deep-well pump, 4
Delivery air-vessel, 53, 62
„ pipe, diameter required, 62

Description of pumps, 4
Dyeworks, pump for, 18
Diameter of pump, to find, 58
„ „ steam-cylinder required, 60
Direct-acting steam pump, diameter of cylinder required, 60
„ „ „ „ speed of, 63
Disc valve, indiarubber, 39
Domestic purposes, pump for, 18
Double-acting air pump, 16
„ „ piston pump, 11
„ „ plunger pump, 12
„ „ ram pump, 12
„ barrel pumps, quantity delivered by, table of, 67, 68
„ „ „ speed of, 63
„ beat clack-valve, 25
„ „ valve, 28
Drainage, pumps for, 18
„ „ modulus of, 66
„ „ valves for, 44
Duty of pump-valves, 23

E.

Earthenware pump, 16
Efficiency, 14
Equality of metal in pumps, 14
„ „ „ valves, 38

F.

Fire engine, make of, 18
„ „ modulus of, 66
„ „ pumps for, 18
Flap-valves, 24
Flat surfaces, 15
Foot-valve, 14
Force required to work a pump, 56
Formulas, 56
Friction in pumps, 59

G.

Gasworks, pumps for, 18
Gelatinous fluids, pumps for, 18
Glass pumps, 16

Glass water-gauge for air-vessels, 55
Glutinous fluids, pumps for, 18
Guard, valve, 40
Guttapercha pump, 16

H.

Hand-pump, 4
„ „ bucket, 45
„ „ valve, 24
Head of water, 65, 70
Hemispherical spill-valve, 27
„ spindle-valve, 27
Hollow plunger pump, 9
„ ram pump, 9
Horizontal double-acting piston pump, 11
„ „ „ plunger pump, 12
„ „ „ ram pump, 12
„ pumps, 11
Horse-power required to raise water, 59
Horses raising water, 66
Hot water, pump for, 14
„ „ valve for, 41
Hydraulic memoranda, 65
Hydrochloric acid, 43

I.

Indiarubber ball valves, 35
„ „ disc and ring valves, 35
„ „ disc valves, 34
„ „ multiple-beat valves, 35
„ „ rotating disc valves, 34
„ „ valves, 34
„ „ valve, guard for, 39, 40
Irrigation, pumps for, 19

L.

Labour of asses, 66
„ „ bullocks, 66
„ „ horses, 66
„ „ men, 65
„ „ mules, 66
Large centrifugal pumps, modulus of, 66
„ mine pumps, speed of, 63
„ vertical plunger pumps used in mines, 7

Leakage, 59
Leather for valves, 37
Length of a bullock walk, 66
Leverage of pump-handles, 56
Lift of pump-valves, 38
„ „ valves, 38
Load on pumps, 56
Loss by leakage, 59
„ „ slip, 59
Low-lift centrifugal pumps, modulus of, 66

M.

Malt liquor, pumps for, 19
Manhole for air-vessels, 55
Material of which pumps should be made, 16
„ „ „ pump-valves should be made, 42
Medium size centrifugal pumps, modulus of, 66
Men, labour of, 65
Milk of lime, 19
Mine pump, 7
„ „ modulus of, 66
Mines, pumps for, 19
Mitre-valves, 26
„ „ conical, 26
„ „ ordinary, 26
Modulus of pumps, 66
Mule, labour of, 66
Multiple-beat indiarubber ring valves, 35
„ „ valves, 33

N.

Naphtha, 20

O.

Oil, pumps for, 20
Ordinary ball valves, 35
„ bucket pump, 4
„ clack-valve, 26
„ direct-acting steam pump, speed of, 63

P.

Paint, pump for, 21
Paper pulp, pump for, 20
Petroleum „ „ 21
Pipe bends, table of, 73
„ delivery, size of, 62
„ flanges, table of, 73
„ suction, size of, 62
„ thickness required, rule for, 62
„ „ „ table of, 71
Piston and plunger pump, 13
„ „ „ „ quantity delivered by, 58
„ pump, double-acting, 11
„ with cup-leather packing, 48
„ „ hemp „ 51
„ „ leather ring „ 49
„ „ metallic „ 49, 50
„ „ water „ 51
Press for cup-leathers, 52
Pressure of steam required, 61
„ „ water, 65
„ „ „ at different heads, rule for, 65
„ „ „ „ „ „ table of, 70
„ on pumps, total, rule for, 56
„ „ „ „ table of, 69
Principle of the action of a pump, 1
Pump, bilge, 21, 42
„ bore-hole, 17
„ bucket, 4
„ „ with butterfly valve, 45
„ „ „ clack-valve, 46
„ „ „ cup-leather packing, 45
„ „ „ indiarubber disc valve, 46
„ „ „ hemp packing, 46
„ „ „ metallic „ 46
„ „ remarks on, 48
„ bucket and plunger, 10
„ centrifugal, modulus of, 66
„ common lift, 4
„ diameter of, to find, 58
„ double-acting piston, 11
„ „ „ ram, 12

Pump, double-barrel, 63
„ earthenware, 16
„ fire-engine, modulus of, 66
„ „ „ make of, 18
„ glass, 16
„ for acid, hydrochloric, 43
„ „ „ strong, 16
„ „ „ weak, 17
„ „ ammoniacal liquor, 17
„ „ anthracene oil, 17
„ „ asphalt, 42
„ „ beer, 17
„ „ benzole, 17
„ „ benzoline, 17
„ „ bilge-water, 42
„ „ bleaching mills, 17
„ „ bore-hole, 17
„ „ breweries, 18
„ „ creosote, 18
„ „ deep wells, 4
„ „ dyeworks, 18
„ „ domestic purposes, 18
„ „ drainage, 18
„ „ „ modulus of, 66
„ „ fire engine, 18
„ „ gasworks, 18
„ „ gelatinous fluids, 18
„ „ glutinous fluids, 18
„ „ hot water, 14
„ „ hydrochloric acid, 43
„ „ irrigation, 19
„ „ malt liquor, 19
„ „ milk of lime, 19
„ „ mines, 19
„ „ „ modulus of, 66
„ „ naphtha, 20
„ „ oil, 20
„ „ paint, 21
„ „ paper pulp, 20
„ „ petroleum, 21
„ „ salt water, 21
„ „ sewage, 21

Pump for strong acid, 16
„ „ sugar solution, 21
„ „ tan liquor, 21
„ „ tar, 21
„ „ treacle, 21
„ „ vinegar, 21
„ „ water, cold, 44
„ „ „ hot, 14
„ „ „ works, 21
„ „ „ „ memoranda on, 65
„ „ „ „ modulus of, 66
„ „ weak acid, 17
„ „ wine, 22
„ passages, 14
„ pistons, 48
„ „ with cup-leather packing, 48
„ „ „ hemp „ 51
„ „ „ metallic „ 50
„ „ „ water „ 51
„ valves, 23
„ „ annular ring, 27
„ „ ball, 35, 40
„ „ bell, 27
„ „ butterfly, 24
„ „ clack, double-beat, 24
„ „ conical mitre, 26
„ „ double-beat, 28
„ „ for acid, hydrochloric, 43
„ „ „ „ strong, 42
„ „ „ „ weak, 43
„ „ „ ammoniacal liquor, 42
„ „ „ anthracene oil, 42
„ „ „ asphalt, 42
„ „ „ benzole, 42
„ „ „ benzoline, 42
„ „ „ bilge-water, 42
„ „ „ breweries, 42
„ „ „ creosote, 43
„ „ „ fire engines, 43
„ „ „ gelatinous fluids, 43
„ „ „ glutinous fluids, 43
„ „ „ gritty water, 41

Pump-valves for hot water, 43
„ „ „ hydrochloric acid, 43
„ „ „ milk of lime, 43
„ „ „ mines, 43
„ „ „ muddy water, 43
„ „ „ naphtha, 44
„ „ „ oil, 44
„ „ „ paper pulp, 44
„ „ „ sewage, 44
„ „ „ sugar solution, 44
„ „ „ tan liquor, 44
„ „ „ tar, 44
„ „ „ water, 44
„ „ „ „ works, 44
„ „ guard, 39, 40
„ „ hemispherical spill, 27
„ „ „ spindle, 27
„ „ indiarubber, 34
„ „ „ disc, 34
„ „ „ „ and ring, 35
„ „ „ multiple-beat ring, 35
„ „ „ rotating disc, 34
„ „ mitre, 26
„ „ multiple-beat, 33
„ „ ordinary mitre, 26
„ „ ring, 28
„ „ spill, 27
„ „ spindle, 27
„ „ with perpendicular lift, 26
„ „ lift of, 37, 38, 63
„ „ remarks on designing, 37
„ „ size of, 63
Pumping engines, speed of, 63
Pumps, stoneware, 16
„ to find size of, 58

Q.

Quantity of water delivered by pumps, rule for, 58
„ „ „ „ „ „ approximately, 59
„ „ „ „ „ „ table of, 67, 68

R.

Remarks on designing pumps, 14
„ „ „ pump-valves, 37
Ring valves, 27
„ and disc valves, indiarubber, 35
Rotating indiarubber disc valves, 34
Rules and formulas, 56

S.

Salt water, pump for, 21
Sewage, „ „ 21
„ valves for, 44
Single-acting plunger pumps, 12
„ „ pumps, 63
„ „ „ quantity delivered by, 58
„ „ „ „ „ „ table of, 67
„ „ „ „ „ „ rule for, 58
„ „ ram pumps, 12
Single-barrel pumps, speed of, 63
Size of pump buckets, table of, 74
„ „ „ clacks, „ „ 63
„ „ „ valves, 63
„ „ „ „ boxes, 39
Slip, quantity of, 59
Small centrifugal pumps, modulus of, 66
„ vertical plunger pumps, 7
Snifting valve for air-vessels, 55
Space in pumps, 14
Spear-rods, table of, 74
Speed of an Indian bullock, 66
„ „ pumps, 63
Spill-valves, 27
Spindle-valves, 27
Steam-cylinder, diameter required, 60
„ pressure required, 61
Stoneware pumps, 16
Strength of cast-iron pipes, 71
Strong acid, pump for, 16
Suction air-vessel, 62
„ branch, 14
„ pipe, diameter required, 62
„ „ position of, 14
„ vacuum vessel, 62

Sudden enlargements and contractions, 14
Sugar solution, pumps for, 21

T.

Table of pipe bends, 73
„ „ „ flanges, 73
„ „ pressure of water at different heads, 70
„ „ quantity discharged by double-barrel pumps, 68
„ „ „ „ „ single-barrel pumps, 67
„ „ „ „ „ treble-barrel pumps, 68
„ „ sizes of buckets, 74
„ „ „ „ clack, 74
„ „ „ „ spear and bucket rods, 74
„ „ strength of pipes, 71
„ „ total pressure on pumps, 69
„ „ weight or pipes, 72
Tan liquor, pumps for, 21
Tar, pumps for, 21
Three-throw pumps, modulus of, 66
Thickness of metal required in pipes, 61
„ „ „ „ „ pumps, 61
Treacle, pumps for, 21
Treble-barrel pumps, quantity delivered by, rule for, 58
„ „ „ „ „ table of, 68
„ „ „ speed of, 63
Total pressure on pumps, rule for, 56
„ „ „ „ table of, 69

U.

Uniformity of metal in pumps, 14
„ „ „ „ valves, 38

V.

Valves, 23
„ annular ring, 27
„ ball, 35
„ bell, 27
„ butterfly, 24
„ clack, 24
„ clack, double-beat, 25
„ conical mitre, 26
„ double-beat, 28
„ „ „ clack, 25

Valves, guard for, 39, 40
„ hemispherical spill, 27
„ „ spindle, 27
„ indiarubber, 34, 39
„ „ disc, 34, 39
„ „ „ and ring, 35
„ „ multiple-beat ring, 35
„ „ rotating disc, 34
„ mitre, 26
„ multiple-beat, 33
„ ordinary mitre, 26
„ ring, 28
„ spill, 26
„ spindle, 26
„ with perpendicular lift, 26
Vertical bucket pump, 4
„ „ and plunger pump, 10
„ plunger pumps, 7
„ pumps, remarks on, 15
Vinegar, pumps for, 21

W.

Water delivered by pumps, approximate quantity of, 59
„ „ „ „ quantity of, 58
„ pumps for, 21
Waterworks, memoranda on, 65
„ pumps for, 21
„ „ modulus of, 66
„ valves for, 44
Weak acid, pumps for, 17
Weight of water, 65
„ „ pipes, rule for, 63
„ „ „ table of, 72
Width of valve-beats, 37
Wine, pumps for, 21
Work done by animals, 65
„ „ „ asses, 66
„ „ „ bullocks, 66
„ „ „ horses, 66
„ „ „ men, 65
„ „ „ mules, 66

LONDON:
PRINTED BY WILLIAM CLOWES AND SONS, LIMITED,
STAMFORD STREET AND CHARING CROSS.

Fig. 1.

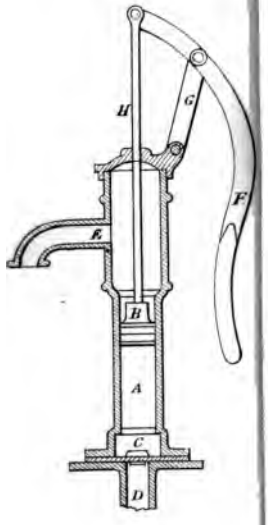


Fig. 3.

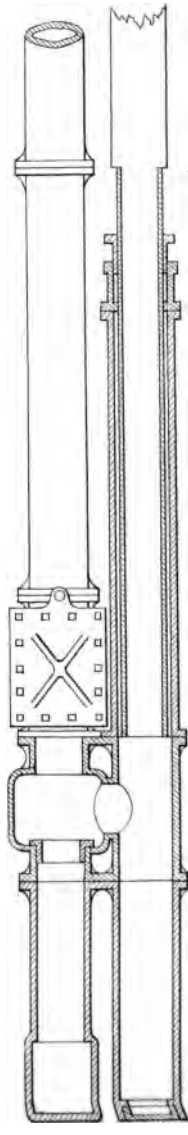


Fig. 9.

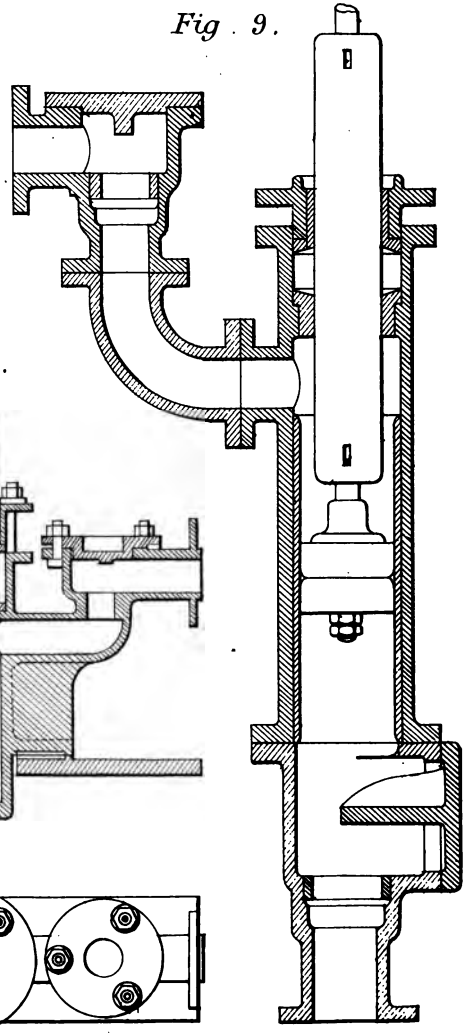


Fig. 7.

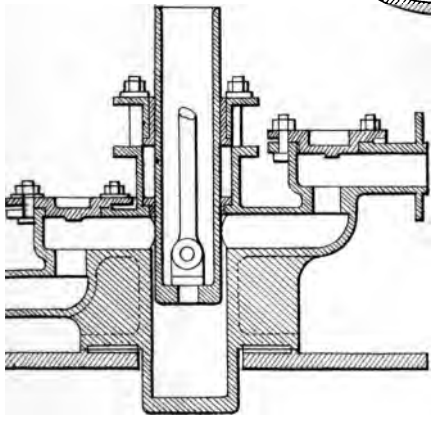


Fig. 8.

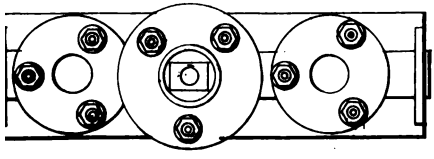
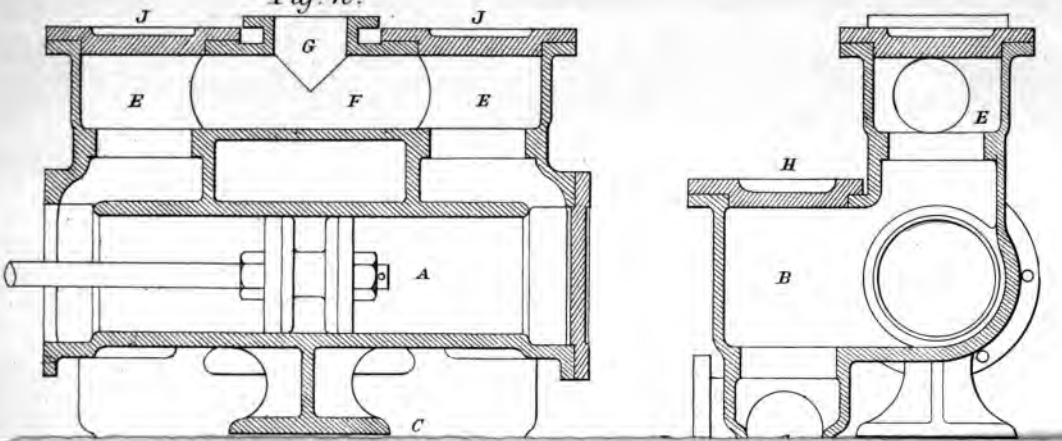


Fig. 10.



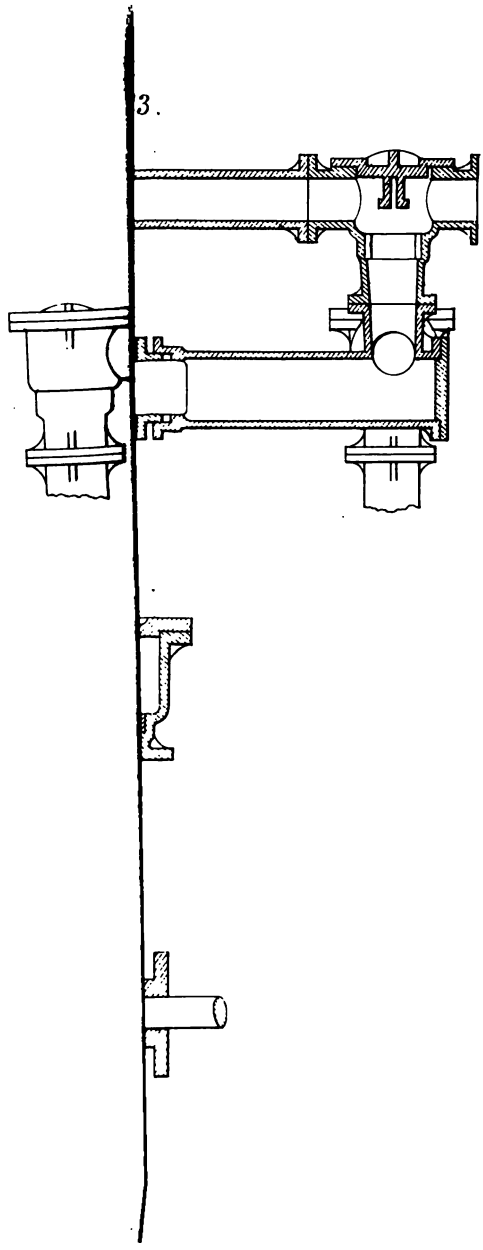

3.

Fig. 17.

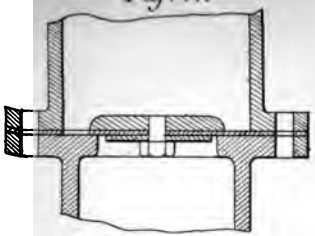


Fig. 18.

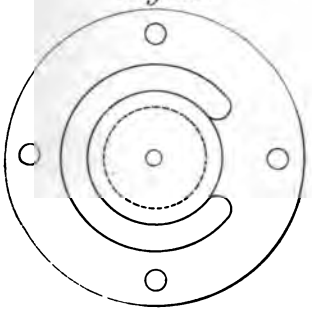


Fig. 19.

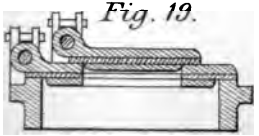


Fig. 20.

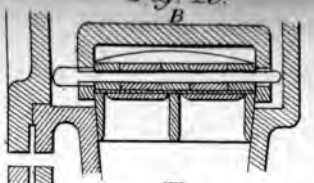


Fig 22

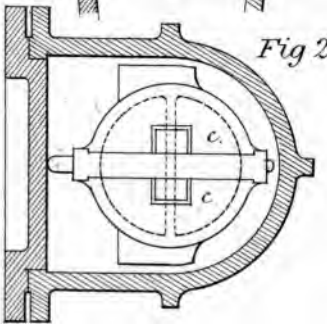


Fig 24.

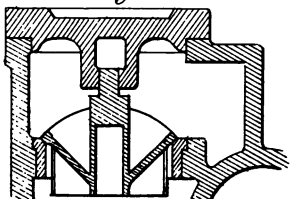


Fig. 21.

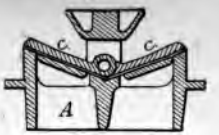


Fig. 25.

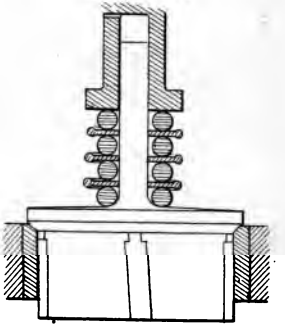
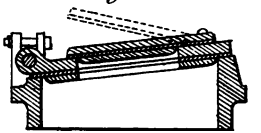
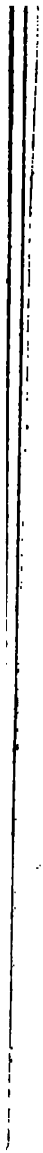


Fig. 23



PLA



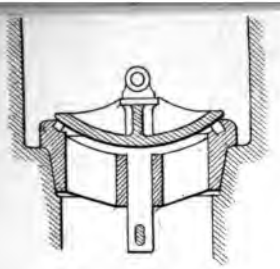


Fig. 27

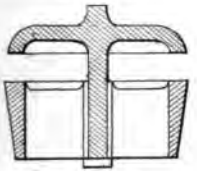
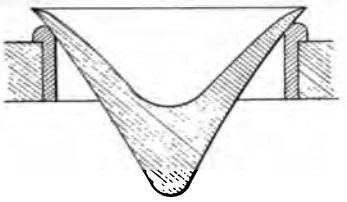


Fig. 28.



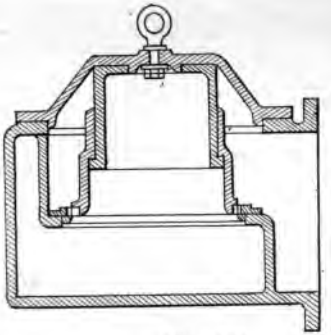
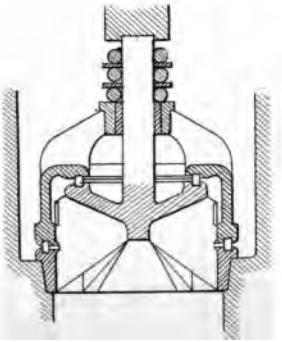


Fig. 30



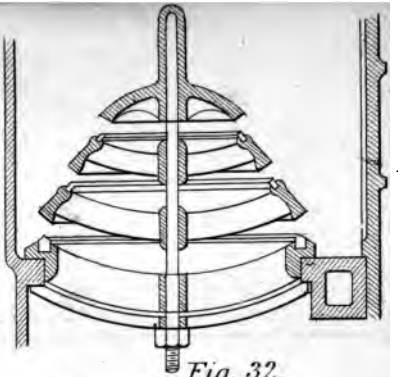


Fig. 32.

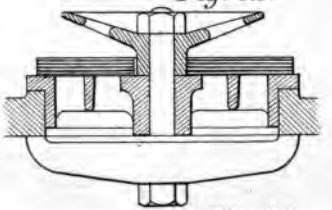
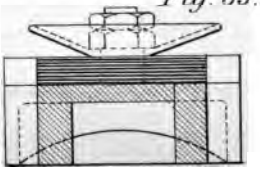


Fig. 33.



PLATE

Fig. 38.

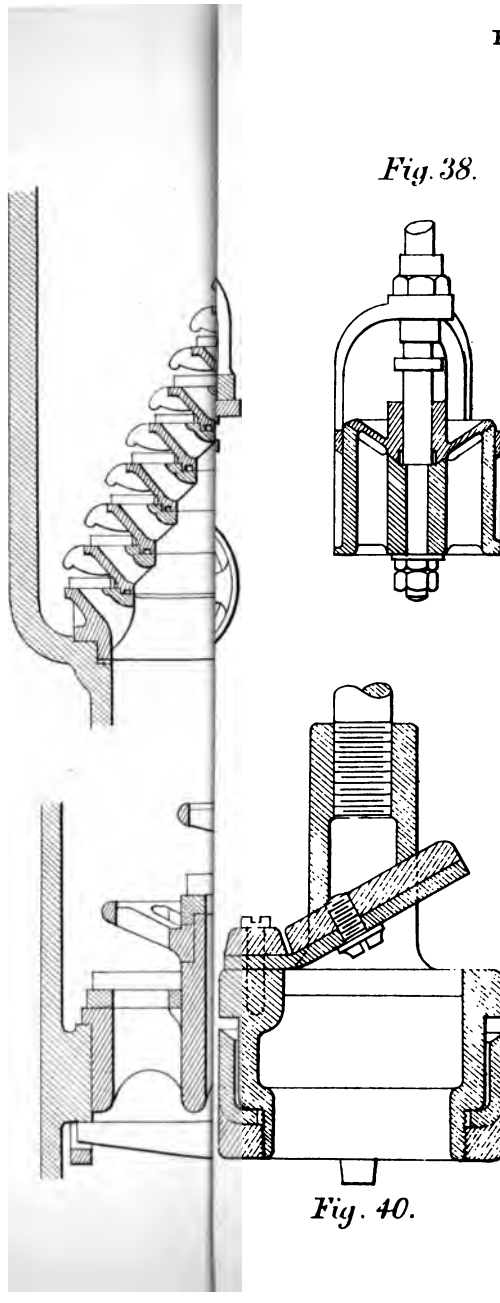


Fig. 40.

Fig. 41.

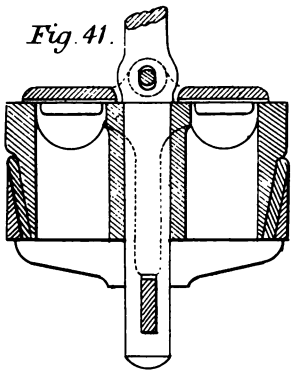


Fig. 42.

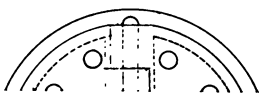


Fig. 43.

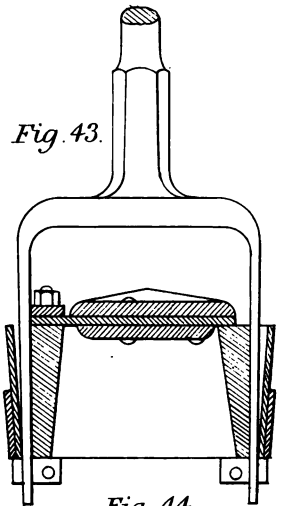


Fig. 44.

Fig 45.

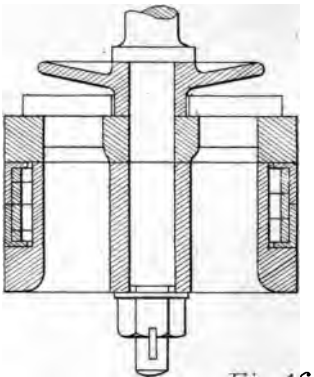


Fig 46

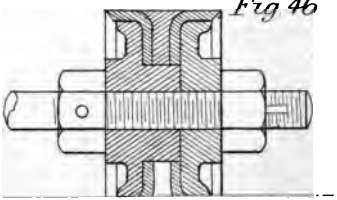


Fig. 41.

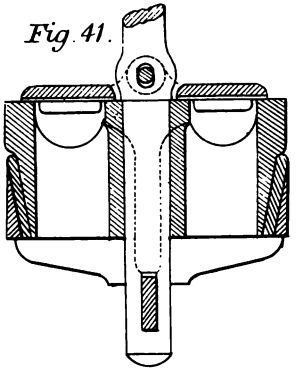


Fig. 42.

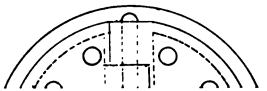


Fig. 43.

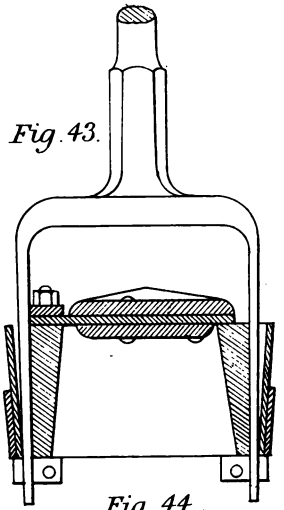


Fig. 44.

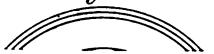


Fig 45.

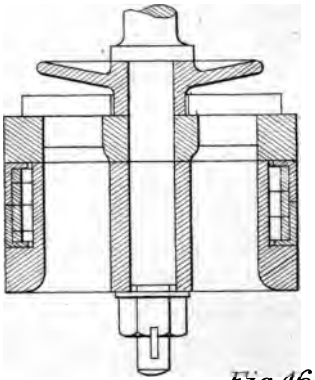


Fig 46

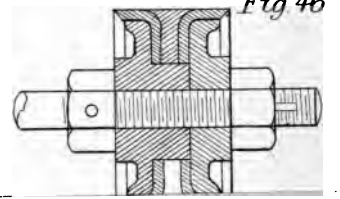


Fig. 48.

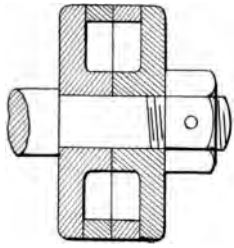


Fig 50

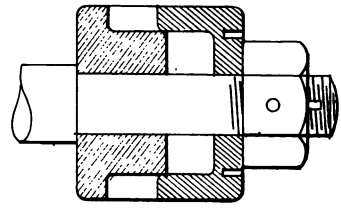


Fig. 49.

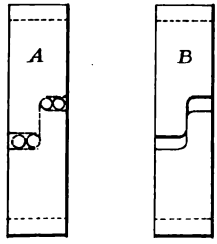


Fig. 51.

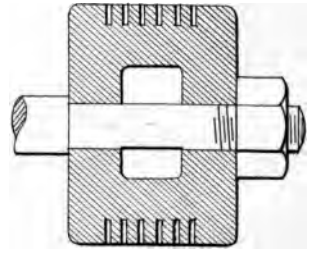


Fig 52.

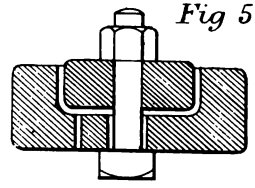
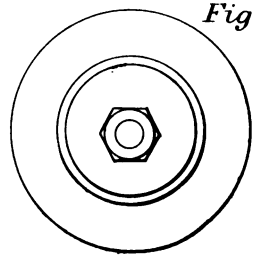


Fig 53.



A Practical Treatise on Coal Mining. By GE
G. ANDRÉ, F.G.S., Assoc. Inst. C.E., Member of the Society of En
With 82 *lithographic plates.* 2 vols., royal 4to, cloth, 3*l.* 12*s.*

Iron Roofs: Examples of Design, Description.
trated with 64 *Working Drawings of Executed Roofs.* By ART
WALMISLEY, Assoc. Mem. Inst. C.E. Imp. 4to, half-morocco, £2

A History of Electric Telegraphy, to the Year
Chiefly compiled from Original Sources, and hitherto Unpublished
ments, by J. J. FAHIE, Mem. Soc. of Tel. Engineers, and of th
national Society of Electricians, Paris. Crown 8vo, cloth, 9*s.*

Spons' Information for Colonial Engineers. E
by J. T. HURST. Demy 8vo, sewed.

No. 1, Ceylon. By ABRAHAM DEANE, C.E. 2*s.* 6*d.*

CONTENTS:

Introductory Remarks — Natural Productions — Architecture and Engineering
graphy, Trade, and Natural History—Principal Stations—Weights and Measures, e

No. 2. Southern Africa, including the Cape Colony, Natal,
Dutch Republics. By HENRY HALL, F.R.G.S., F.R.C.I.
Map. 3*s.* 6*d.*

CONTENTS:

General Description of South Africa—Physical Geography with reference to En
Operations—Notes on Labour and Material in Cape Colony—Geological Notes
Formation in South Africa—Engineering Instruments for Use in South Africa—
Public Works in Cape Colony: Railways, Mountain Roads and Passes, Harbou
Bridges, Gas Works, Irrigation and Water Supply, Lighthouses, Drainage and
Engineering, Public Buildings, Mines—Table of Woods in South Africa—Animals
Draught Purposes—Statistical Notes—Table of Distances—Rates of Carriage, etc.

No. 3. India. By F. C. DANVERS, Assoc. Inst. C.E. With Map

CONTENTS:

Physical Geography of India—Building Materials—Roads—Railways—Bridge
tion — River Works — Harbours — Lighthouse Buildings — Native Labour — The
Trees of India—Money—Weights and Measures—Glossary of Indian Terms, etc.

A Practical Treatise on Casting and Fou
including descriptions of the modern machinery employed in the
N. E. SPRETSON, Engineer. Third edition, with 82 *plates* d
scale, 412 pp., demy 8vo, cloth, 18*s.*

Steam Heating for Buildings; or, Hints to
Fitters, being a description of Steam Heating Apparatus for V
and Ventilating Private Houses and Large Buildings, with rem
Steam, Water, and Air in their relation to Heating. By W. J. B
With many illustrations. Fourth edition, crown 8vo, cloth, 10*s.*

The Depreciation of Factories and their Valuation. By EWING MATHESON, M. Inst. C.E. 8vo, cloth, 6*s.*

A Handbook of Electrical Testing. By H. R. KEMPE, M.S.T.E. Third edition, revised and enlarged, crown 8vo, cloth, 15*s.*

Gas Works: their Arrangement, Construction, Plant, and Machinery. By F. COLYER, M. Inst. C.E. *With* 31 *folding plates*, 8vo, cloth, 24*s.*

The Clerk of Works: a Vade-Mecum for all engaged in the Superintendence of Building Operations. By G. G. HOSKINS, F.R.I.B.A. Third edition, fcap. 8vo, cloth, 1*s.* 6*d.*

American Foundry Practice: Treating of Loam, Dry Sand, and Green Sand Moulding, and containing a Practical Treatise upon the Management of Cupolas, and the Melting of Iron. By T. D. WEST, Practical Iron Moulder and Foundry Foreman. Second edition, *with numerous illustrations*, crown 8vo, cloth, 10*s.* 6*d.*

The Maintenance of Macadamised Roads. By T. CODRINGTON, M.I.C.E, F.G.S., General Superintendent of County Roads for South Wales. 8vo, cloth, 6*s.*

Hydraulic Steam and Hand Power Lifting and Pressing Machinery. By FREDERICK COLYER, M. Inst. C.E., M. Inst. M.E. *With* 73 *plates*, 8vo, cloth, 18*s.*

Pumps and Pumping Machinery. By F. COLYER, M.I.C.E., M.I.M.E. *With* 23 *folding plates*, 8vo, cloth, 12*s.* 6*d.*

The Municipal and Sanitary Engineer's Handbook. By H. PERCY BOULNOIS, Mem. Inst. C.E., Borough Engineer, Portsmouth. *With numerous illustrations*, demy 8vo, cloth, 12*s.* 6*d.*

CONTENTS:

The Appointment and Duties of the Town Surveyor—Traffic—Macadamised Roadways—Steam Rolling—Road Metal and Breaking—Pitched Pavements—Asphalte—Wood Pavements—Footpaths—Kerbs and Gutters—Street Naming and Numbering—Street Lighting—Sewerage—Ventilation of Sewers—Disposal of Sewage—House Drainage—Disinfection—Gas and Water Companies, &c., Breaking up Streets—Improvement of Private Streets—Borrowing Powers—Artizans' and Labourers' Dwellings—Public Conveniences—Scavenging, including Street Cleansing—Watering and the Removing of Snow—Planting Street Trees—Deposit of Plans—Dangerous Buildings—Hoardings—Obstructions—Improving Street Lines—Cellar Openings—Public Pleasure Grounds—Cemeteries—Mortuaries—Cattle and Ordinary Markets—Public Slaughter-houses, etc.—Giving numerous Forms of Notices, Specifications, and General Information upon these and other subjects of great importance to Municipal Engineers and others engaged in Sanitary Work.

Tables of the Principal Speeds occurring in Mechanical Engineering, expressed in metres in a second. By P. KEERAYEFF, Chief Mechanic of the Obouchoff Steel Works, St. Petersburg; translated by SERGIUS KERN, M.E. Fcap. 8vo, sewed, 6*d.*

A Treatise on the Origin, Progress, Prevention, and Cure of Dry Rot in Timber; with Remarks on the Means of Preserving Wood from Destruction by Sea-Worms, Beetles, Ants, etc. By THOMAS ALLEN BRITTON, late Surveyor to the Metropolitan Board of Works, etc., etc. *With* 10 *plates*, crown 8vo, cloth, 7*s.* 6*d.*

Metrical Tables. By G. L. MOLESWORTH, M.I.C.E. 32mo, cloth, 1*s.* 6*d.*

CONTENTS.

General—Linear Measures—Square Measures—Cubic Measures—Measures of Capacity—Weights—Combinations—Thermometers.

Elements of Construction for Electro-Magnets. By Count TH. DU MONCEL, Mem. de l'Institut de France. Translated from the French by C. J. WHARTON. Crown 8vo, cloth, 4*s.* 6*d.*

Electro-Telegraphy. By FREDERICK S. BEECHEY Telegraph Engineer. A Book for Beginners. *Illustrated.* Fcap. 8vo sewed, 6*d.*

Handrailing: by the Square Cut. By JOHN JONES Staircase Builder. Part Second, *with eight plates*, 8vo, cloth, 3*s.* 6*d.*

Practical Electrical Units Popularly Explained, with *numerous illustrations* and Remarks. By JAMES SWINBURNE, late J. W. Swan and Co., Paris, late of Brush-Swan Electric Light Company U.S.A. 18mo, cloth, 1*s.* 6*d.*

Philipp Reis, Inventor of the Telephone: A Biographical Sketch. With Documentary Testimony, Translations of the Original Papers of the Inventor, &c. By SILVANUS P. THOMPSON, B.A., Dr. Sc. Professor of Experimental Physics in University College, Bristol. *With illustrations*, 8vo, cloth, 7*s.* 6*d.*

A Treatise on the Use of Belting for the Transmission of Power. By J. H. COOPER. Second edition, *illustrated*, 8vo cloth, 15*s.*

A Pocket-Book of Useful Formulæ and Memoranda for Civil and Mechanical Engineers. By GUILFORD L. MOLESWORTH, Mem. Inst. C.E., Consulting Engineer to the Government of India for State Railways. *With numerous illustrations*, 744 pp. Twenty-first edition, revised and enlarged, 32mo, roan, 6*s.*

SYNOPSIS OF CONTENTS:

Surveying, Levelling, etc.—Strength and Weight of Materials—Earthwork, Brickwork, Masonry, Arches, etc.—Struts, Columns, Beams, and Trusses—Flooring, Roofing, and Roof Trusses—Girders, Bridges, etc.—Railways and Roads—Hydraulic Formulæ—Canals, Sewers, Waterworks, Docks—Irrigation and Breakwaters—Gas, Ventilation, and Warming—Heat, Light, Colour, and Sound—Gravity: Centres, Forces, and Powers—Millwork, Teeth of Wheels, Shafting, etc.—Workshop Recipes—Sundry Machinery—Animal Power—Steam and the Steam Engine—Water-power, Water-wheels, Turbines, etc.—Wind and Windmills—Steam Navigation, Ship Building, Tonnage, etc.—Gunnery, Projectiles, etc.—Weights, Measures, and Money—Trigonometry, Conic Sections, and Curves—Telegraphy—Mensuration—Tables of Areas and Circumference, and Arcs of Circles—Logarithms, Square and Cube Roots, Powers—Reciprocals, etc.—Useful Numbers—Differential and Integral Calculus—Algebraic Signs—Telegraphic Construction and Formulæ.

Spons' Tables and Memoranda for Engineers; selected and arranged by J. T. HURST, C.E., Author of 'Architectural Surveyors' Handbook,' 'Hurst's Tredgold's Carpentry,' etc. Seventh edition, 64mo, roan, gilt edges, 1*s.*; or in cloth case, 1*s.* 6*d.*

This work is printed in a pearl type, and is so small, measuring only 2¼ in. by 1¼ in. by ¾ in. thick, that it may be easily carried in the waistcoat pocket.

"It is certainly an extremely rare thing for a reviewer to be called upon to notice a volume measuring but 2⅛ in. by 1⅛ in., yet these dimensions faithfully represent the size of the handy little book before us. The volume—which contains 118 printed pages, besides a few blank pages for memoranda—is, in fact, a true pocket-book, adapted for being carried in the waistcoat pocket, and containing a far greater amount and variety of information than most people would imagine could be compressed into so small a space. . . . . The little volume has been compiled with considerable care and judgment, and we can cordially recommend it to our readers as a useful little pocket companion."—*Engineering.*

A Practical Treatise on Natural and Artificial Concrete, its Varieties and Constructive Adaptations. By HENRY REID, Author of the 'Science and Art of the Manufacture of Portland Cement.' New Edition, *with* 59 *woodcuts and* 5 *plates*, 8vo, cloth, 15*s.*

Hydrodynamics: Treatise relative to the Testing of Water-Wheels and Machinery, with various other matters pertaining to Hydrodynamics. By JAMES EMERSON. *With numerous illustrations*, 360 pp. Third edition, crown 8vo, cloth, 4*s.* 6*d.*

Electricity as a Motive Power. By Count TH. DU MONCEL, Membre de l'Institut de France, and FRANK GERALDY, Ingénieur des Ponts et Chaussées. Translated and Edited, with Additions, by C. J. WHARTON, Assoc. Soc. Tel. Eng. and Elec. *With* 113 *engravings and diagrams*, crown 8vo, cloth, 7*s.* 6*d.*

Hints on Architectural Draughtsmanship. By G. W. OXFORD HALLATT. Fcap. 8vo, cloth, 1*s.* 6*d.*

Dynamo-Electric Machinery: A Manual for Students of Electrotechnics. By SILVANUS P. THOMPSON, B.A., D.Sc., Professor of Physics in University College, Bristol, etc. etc. Second Edition. 8vo, cloth, 12s. 6d.

The New Formula for Mean Velocity of Discharge of Rivers and Canals. By W. R. KUTTER. Translated from articles in the 'Cultur-Ingénieur,' by LOWIS D'A. JACKSON, Assoc. Inst. C.E. 8vo, cloth, 12*s.* 6*d.*

Practical Hydraulics; a Series of Rules and Tables for the use of Engineers, etc., etc. By THOMAS BOX. Fifth edition, *numerous plates*, post 8vo, cloth, 5*s.*

A Practical Treatise on the Construction of Horizontal and Vertical Waterwheels, specially designed for the use of operative mechanics. By WILLIAM CULLEN, Millwright and Engineer. *With* 11 *plates.* Second edition, revised and enlarged, small 4to, cloth, 12*s.* 6*d.*

Tin: Describing the Chief Methods of Mining, Dressing and Smelting it abroad; with Notes upon Arsenic, Bismuth and Wolfram. By ARTHUR G. CHARLETON, Mem. American Inst. of Mining Engineers. *With plates*, 8vo, cloth, 12*s.* 6*d.*

Perspective, Explained and Illustrated. By G. S. CLARKE, Capt. R.E. *With illustrations*, 8vo, cloth, 3*s.* 6*d.*

The Essential Elements of Practical Mechanics; based on the Principle of Work, designed for Engineering Students. By OLIVER BYRNE, formerly Professor of Mathematics, College for Civil Engineers. Third edition, *with* 148 *wood engravings*, post 8vo, cloth, 7*s.* 6*d.*

CONTENTS:

Chap. 1. How Work is Measured by a Unit, both with and without reference to a Unit Time—Chap. 2. The Work of Living Agents, the Influence of Friction, and introduces some of the most beautiful Laws of Motion—Chap. 3. The principles expounded in the first and second chapters are applied to the Motion of Bodies—Chap. 4. The Transmission of Work by Simple Machines—Chap. 5. Useful Propositions and Rules.

The Practical Millwright and Engineer's Ready Reckoner; or Tables for finding the diameter and power of cog-wheels, diameter, weight, and power of shafts, diameter and strength of bolts, etc. By THOMAS DIXON. Fourth edition, 12mo, cloth, 3*s.*

Breweries and Maltings: their Arrangement, Construction, Machinery, and Plant. By G. SCAMELL, F.R.I.B.A. Second edition, revised, enlarged, and partly rewritten. By F. COLYER, M.I.C.E., M.I.M.E. *With* 20 *plates*, 8vo, cloth, 18*s.*

A Practical Treatise on the Manufacture of Starch, Glucose, Starch-Sugar, and Dextrine, based on the German of L. Von Wagner, Professor in the Royal Technical School, Buda Pesth, and other authorities. By JULIUS FRANKEL; edited by ROBERT HUTTER, proprietor of the Philadelphia Starch Works. *With* 58 *illustrations*, 344 pp., 8vo, cloth, 18*s.*

A Practical Treatise on Mill-gearing, Wheels, Shafts, Riggers, etc.; for the use of Engineers. By THOMAS BOX. Third edition, *with* 11 *plates*. Crown 8vo, cloth, 7*s*. 6*d*.

Mining Machinery: a Descriptive Treatise on the Machinery, Tools, and other Appliances used in Mining. By G. G. ANDRÉ, F.G.S., Assoc. Inst. C.E., Mem. of the Society of Engineers. Royal 4to, uniform with the Author's Treatise on Coal Mining, containing 182 *plates*, accurately drawn to scale, with descriptive text, in 2 vols., cloth, 3*l*. 12*s*.

CONTENTS:

Machinery for Prospecting, Excavating, Hauling, and Hoisting—Ventilation—Pumping—Treatment of Mineral Products, including Gold and Silver, Copper, Tin, and Lead, Iron Coal, Sulphur, China Clay, Brick Earth, etc.

Tables for Setting out Curves for Railways, Canals, Roads, etc., varying from a radius of five chains to three miles. By A. KENNEDY and R. W. HACKWOOD. *Illustrated*, 32mo, cloth, 2*s*. 6*d*.

The Science and Art of the Manufacture of Portland Cement, with observations on some of its constructive applications. *With* 66 *illustrations*. By HENRY REID, C.E., Author of 'A Practical Treatise on Concrete,' etc., etc. 8vo, cloth, 18*s*.

The Draughtsman's Handbook of Plan and Map Drawing; including instructions for the preparation of Engineering, Architectural, and Mechanical Drawings. *With numerous illustrations in the text, and* 33 *plates* (15 *printed in colours*). By G. G. ANDRÉ, F.G.S., Assoc. Inst. C.E. 4to, cloth, 9*s*.

CONTENTS:

The Drawing Office and its Furnishings—Geometrical Problems—Lines, Dots, and their Combinations—Colours, Shading, Lettering, Bordering, and North Points—Scales—Plotting—Civil Engineers' and Surveyors' Plans—Map Drawing—Mechanical and Architectural Drawing—Copying and Reducing Trigonometrical Formulæ, etc., etc.

The Boiler-maker's and Iron Ship-builder's Companion, comprising a series of original and carefully calculated tables, of the utmost utility to persons interested in the iron trades. By JAMES FODEN, author of 'Mechanical Tables,' etc. Second edition revised, *with illustrations*, crown 8vo, cloth, 5*s*.

Rock Blasting: a Practical Treatise on the means employed in Blasting Rocks for Industrial Purposes. By G. G. ANDRÉ, F.G.S., Assoc. Inst. C.E. *With* 56 *illustrations and* 12 *plates*, 8vo, cloth, 10*s*. 6*d*.

Painting and Painters' Manual: a Book of Facts for Painters and those who Use or Deal in Paint Materials. By C. L. CONDIT and J. SCHELLER. *Illustrated*, 8vo, cloth, 10*s*. 6*d*.

A Treatise on Ropemaking as practised in public and private Rope-yards, with a Description of the Manufacture, Rules, Tables of Weights, etc., adapted to the Trade, Shipping, Mining, Railways, Builders, etc. By R. CHAPMAN, formerly foreman to Messrs. Huddart and Co., Limehouse, and late Master Ropemaker to H.M. Dockyard, Deptford. Second edition, 12mo, cloth, 3*s.*

Laxton's Builders' and Contractors' Tables; for the use of Engineers, Architects, Surveyors, Builders, Land Agents, and others. Bricklayer, containing 22 tables, with nearly 30,000 calculations. 4to, cloth, 5*s.*

Laxton's Builders' and Contractors' Tables. Excavator, Earth, Land, Water, and Gas, containing 53 tables, with nearly 24,000 calculations. 4to, cloth, 5*s.*

Sanitary Engineering: a Guide to the Construction of Works of Sewerage and House Drainage, with Tables for facilitating the calculations of the Engineer. By BALDWIN LATHAM, C.E., M. Inst. C.E., F,G.S., F.M.S., Past-President of the Society of Engineers. Second edition, *with numerous plates and woodcuts*, 8vo, cloth, 1*l.* 10*s.*

Screw Cutting Tables for Engineers and Machinists, giving the values of the different trains of Wheels required to produce Screws of any pitch, calculated by Lord Lindsay, M.P., F.R.S., F.R.A.S., etc. Cloth, oblong, 2*s.*

Screw Cutting Tables, for the use of Mechanical Engineers, showing the proper arrangement of Wheels for cutting the Threads of Screws of any required pitch, with a Table for making the Universal Gas-pipe Threads and Taps. By W. A. MARTIN, Engineer. Second edition, oblong, cloth, 1*s.*, or sewed, 6*d.*

A Treatise on a Practical Method of Designing Slide-Valve Gears by Simple Geometrical Construction, based upon the principles enunciated in Euclid's Elements, and comprising the various forms of Plain Slide-Valve and Expansion Gearing; together with Stephenson's, Gooch's, and Allan's Link-Motions, as applied either to reversing or to variable expansion combinations. By EDWARD J. COWLING WELCH, Memb. Inst. Mechanical Engineers. Crown 8vo, cloth, 6*s.*

Cleaning and Scouring: a Manual for Dyers, Laundresses, and for Domestic Use. By S. CHRISTOPHER. 18mo, sewed, 6*d.*

A Handbook of House Sanitation; for the use of all persons seeking a Healthy Home. A reprint of those portions of Mr. Bailey-Denton's Lectures on Sanitary Engineering, given before the School of Military Engineering, which related to the "Dwelling," enlarged and revised by his Son, E. F. BAILEY-DENTON, C.E., B.A. *With* 140 *illustrations*, 8vo, cloth, 8*s.* 6*d*

A Glossary of Terms used in Coal Mining. By WILLIAM STUKELEY GRESLEY, Assoc. Mem. Inst. C.E., F.G.S., Member of the North of England Institute of Mining Engineers. *Illustrated with numerous woodcuts and diagrams,* crown 8vo, cloth, 5*s.*

A Pocket-Book for Boiler Makers and Steam Users, comprising a variety of useful information for Employer and Workman, Government Inspectors, Board of Trade Surveyors, Engineers in charge of Works and Slips, Foremen of Manufactories, and the general Steam-using Public. By MAURICE JOHN SEXTON. Second edition, royal 32mo, roan, gilt edges, 5*s.*

Electrolysis: a Practical Treatise on Nickeling, Coppering, Gilding, Silvering, the Refining of Metals, and the treatment of Ores by means of Electricity. By HIPPOLYTE FONTAINE, translated from the French by J. A. BERLY, C.E., Assoc. S.T.E. *With engravings.* 8vo, cloth, 9*s.*

A Practical Treatise on the Steam Engine, containing Plans and Arrangements of Details for Fixed Steam Engines, with Essays on the Principles involved in Design and Construction. By ARTHUR RIGG, Engineer, Member of the Society of Engineers and of the Royal Institution of Great Britain. Demy 4to, *copiously illustrated with woodcuts and* 96 *plates,* in one Volume, half-bound morocco, 2*l.* 2*s.*; or cheaper edition, cloth, 25*s.*

This work is not, in any sense, an elementary treatise, or history of the steam engine, but is intended to describe examples of Fixed Steam Engines without entering into the wide domain of locomotive or marine practice. To this end illustrations will be given of the most recent arrangements of Horizontal, Vertical, Beam, Pumping, Winding, Portable, Semi-portable, Corliss, Allen, Compound, and other similar Engines, by the most eminent Firms in Great Britain and America. The laws relating to the action and precautions to be observed in the construction of the various details, such as Cylinders, Pistons, Piston-rods, Connecting-rods, Cross-heads, Motion-blocks, Eccentrics, Simple, Expansion, Balanced, and Equilibrium Slide-valves, and Valve-gearing will be minutely dealt with. In this connection will be found articles upon the Velocity of Reciprocating Parts and the Mode of Applying the Indicator, Heat and Expansion of Steam Governors, and the like. It is the writer's desire to draw illustrations from every possible source, and give only those rules that present practice deems correct.

Barlow's Tables of Squares, Cubes, Square Roots, Cube Roots, Reciprocals of all Integer Numbers up to 10,000. Post 8vo, cloth, 6*s.*

Camus (M.) Treatise on the Teeth of Wheels, demonstrating the best forms which can be given to them for the purposes of Machinery, such as Mill-work and Clock-work, and the art of finding their numbers. Translated from the French, with details of the present practice of Millwrights, Engine Makers, and other Machinists, by ISAAC HAWKINS. Third edition, *with* 18 *plates,* 8vo, cloth, 5*s.*

A Practical Treatise on the Science of Land and Engineering Surveying, Levelling, Estimating Quantities, etc., with a general description of the several Instruments required for Surveying, Levelling, Plotting, etc. By H. S. MERRETT. Fourth edition, revised by G. W. USILL, Assoc. Mem. Inst. C.E. 41 *plates, with illustrations and tables*, royal 8vo, cloth, 12*s.* 6*d.*

PRINCIPAL CONTENTS:

Part 1. Introduction and the Principles of Geometry. Part 2. Land Surveying; comprising General Observations—The Chain—Offsets Surveying by the Chain only—Surveying Hilly Ground—To Survey an Estate or Parish by the Chain only—Surveying with the Theodolite—Mining and Town Surveying—Railroad Surveying—Mapping—Division and Laying out of Land—Observations on Enclosures—Plane Trigonometry. Part 3. Levelling—Simple and Compound Levelling—The Level Book—Parliamentary Plan and Section—Levelling with a Theodolite—Gradients—Wooden Curves—To Lay out a Railway Curve—Setting out Widths. Part 4. Calculating Quantities generally for Estimates—Cuttings and Embankments—Tunnels—Brickwork—Ironwork—Timber Measuring. Part 5. Description and Use of Instruments in Surveying and Plotting—The Improved Dumpy Level—Troughton's Level—The Prismatic Compass—Proportional Compass—Box Sextant—Vernier—Pantagraph—Merrett's Improved Quadrant—Improved Computation Scale—The Diagonal Scale—Straight Edge and Sector. Part 6. Logarithms of Numbers—Logarithmic Sines and Co-Sines, Tangents and Co-Tangents—Natural Sines and Co-Sines—Tables for Earthwork, for Setting out Curves, and for various Calculations, etc., etc., etc.

Saws: the History, Development, Action, Classification, and Comparison of Saws of all kinds. By ROBERT GRIMSHAW. *With* 220 *illustrations*, 4to, cloth, 12*s.* 6*d.*

A Supplement to the above; containing additional practical matter, more especially relating to the forms of Saw Teeth for special material and conditions, and to the behaviour of Saws under particular conditions. *With* 120 *illustrations*, cloth, 9*s.*

A Guide for the Electric Testing of Telegraph Cables. By Capt. V. HOSKIÆR, Royal Danish Engineers. *With illustrations*, second edition, crown 8vo, cloth, 4*s.* 6*d.*

Laying and Repairing Electric Telegraph Cables. By Capt. V. HOSKIÆR, Royal Danish Engineers. Crown 8vo, cloth, 3*s.* 6*d.*

A Pocket-Book of Practical Rules for the Proportions of Modern Engines and Boilers for Land and Marine purposes. By N. P. BURGH. Seventh edition, royal 32mo, roan, 4*s.* 6*d.*

The Assayer's Manual: an Abridged Treatise on the Docimastic Examination of Ores and Furnace and other Artificial Products. By BRUNO KERL. Translated by W. T. BRANNT. *With* 65 *illustrations*, 8vo, cloth, 12*s.* 6*d.*

The Steam Engine considered as a Heat Engine: a Treatise on the Theory of the Steam Engine, illustrated by Diagrams, Tables, and Examples from Practice. By JAS. H. COTTERILL, M.A., F.R.S., Professor of Applied Mechanics in the Royal Naval College. 8vo, cloth, 12*s.* 6*d.*

Electricity: its Theory, Sources, and Applications. By J. T. SPRAGUE, M.S.T.E. Second edition, revised and enlarged, *with numerous illustrations*, crown 8vo, cloth, 15*s*.

The Practice of Hand Turning in Wood, Ivory, Shell, etc., with Instructions for Turning such Work in Metal as may be required in the Practice of Turning in Wood, Ivory, etc.; also an Appendix on Ornamental Turning. (A book for beginners.) By FRANCIS CAMPIN. Third edition, *with wood engravings*, crown 8vo, cloth, 6*s*.

CONTENTS:

On Lathes—Turning Tools—Turning Wood—Drilling—Screw Cutting—Miscellaneous Apparatus and Processes—Turning Particular Forms—Staining—Polishing—Spinning Metals—Materials—Ornamental Turning, etc.

Health and Comfort in House Building, or Ventilation with Warm Air by Self-Acting Suction Power, with Review of the mode of Calculating the Draught in Hot-Air Flues, and with some actual Experiments. By J. DRYSDALE, M.D., and J. W. HAYWARD, M.D. Second edition, with Supplement, *with plates*, demy 8vo, cloth, 7*s*. 6*d*.

Treatise on Watchwork, Past and Present. By the Rev. H. L. NELTHROPP, M.A., F.S.A. *With* 32 *illustrations*, crown 8vo, cloth, 6*s*. 6*d*.

CONTENTS:

Definitions of Words and Terms used in Watchwork—Tools—Time—Historical Summary—On Calculations of the Numbers for Wheels and Pinions; their Proportional Sizes, Trains, etc.—Of Dial Wheels, or Motion Work—Length of Time of Going without Winding up—The Verge—The Horizontal—The Duplex—The Lever—The Chronometer—Repeating Watches—Keyless Watches—The Pendulum, or Spiral Spring—Compensation—Jewelling of Pivot Holes—Clerkenwell—Fallacies of the Trade—Incapacity of Workmen—How to Choose and Use a Watch, etc.

Notes in Mechanical Engineering. Compiled principally for the use of the Students attending the Classes on this subject at the City of London College. By HENRY ADAMS, Mem. Inst. M.E., Mem. Inst. C.E., Mem. Soc. of Engineers. Crown 8vo, cloth, 2*s*. 6*d*.

Algebra Self-Taught. By W. P. HIGGS, M.A., D.Sc., LL.D., Assoc. Inst. C.E., Author of 'A Handbook of the Differential Calculus,' etc. Second edition, crown 8vo, cloth, 2*s*. 6*d*.

CONTENTS:

Symbols and the Signs of Operation—The Equation and the Unknown Quantity—Positive and Negative Quantities—Multiplication—Involution—Exponents—Negative Exponents—Roots, and the Use of Exponents as Logarithms—Logarithms—Tables of Logarithms and Proportionate Parts—Transformation of System of Logarithms—Common Uses of Common Logarithms—Compound Multiplication and the Binomial Theorem—Division, Fractions, and Ratio—Continued Proportion—The Series and the Summation of the Series—Limit of Series—Square and Cube Roots—Equations—List of Formulæ, etc.

Spons' Dictionary of Engineering, Civil, Mechanical, Military, and Naval; with technical terms in French, German, Italian, and Spanish, 3100 pp., and *nearly* 8000 *engravings*, in super-royal 8vo, *in 8 divisions*, 5*l*. 8*s*. Complete in 3 vols., cloth, 5*l*. 5*s*. Bound in a *superior* manner, half-morocco, top edge gilt, 3 vols., 6*l*. 12*s*.

Canoe and Boat Building: a complete Manual for Amateurs, containing plain and comprehensive directions for the construction of Canoes, Rowing and Sailing Boats, and Hunting Craft. By W. P. STEPHENS. *With numerous illustrations and 24 plates of Working Drawings.* Crown 8vo, cloth, *7s. 6d.*

Cultural Industries for Queensland: Papers on the cultivation of useful Plants suited to the climate of Queensland, their value as Food, in the Arts, and in Medicine, and methods of obtaining their products. By L. A. BERNAYS, F.L.S., F.R.G.S. 8vo, half calf, *7s. 6d.* The same, in cloth, *6s.*

Proceedings of the National Conference of Electricians, Philadelphia, October 8th to 13th, 1884. 18mo, cloth, *3s.*

Dynamo-Electricity, its Generation, Application, Transmission, Storage, and Measurement. By G. B. PRESCOTT. *With 545 illustrations.* 8vo, cloth, *1l. 1s.*

Domestic Electricity for Amateurs. Translated from the French of E. HOSPITALIER, Editor of "L'Electricien," by C. J. WHARTON, Assoc. Soc. Tel. Eng. *Numerous illustrations.* Demy 8vo, cloth, *9s.*

CONTENTS:

1. Production of the Electric Current—2. Electric Bells—3. Automatic Alarms—4. Domestic Telephones—5. Electric Clocks—6. Electric Lighters—7. Domestic Electric Lighting—8. Domestic Application of the Electric Light—9. Electric Motors—10. Electrical Locomotion—11. Electrotyping, Plating, and Gilding—12. Electric Recreations—13. Various applications—Workshop of the Electrician.

Wrinkles in Electric Lighting. By VINCENT STEPHEN. *With illustrations.* 18mo, cloth, *2s. 6d.*

CONTENTS:

1. The Electric Current and its production by Chemical means—2. Production of Electric Currents by Mechanical means—3. Dynamo-Electric Machines—4. Electric Lamps—5. Lead—6. Ship Lighting.

The Practical Flax Spinner; being a Description of the Growth, Manipulation, and Spinning of Flax and Tow. By LESLIE C. MARSHALL, of Belfast. *With illustrations.* 8vo, cloth, *15s.*

Foundations and Foundation Walls for all classes of Buildings, Pile Driving, Building Stones and Bricks, Pier and Wall construction, Mortars, Limes, Cements, Concretes, Stuccos, &c. 64 *illustrations.* By G. T. POWELL and F. BAUMAN. 8vo, cloth, *10s. 6d.*

The British Jugernath. Free Trade! Fair Trade!! *Reciprocity!!!* and Retaliation !!!! By G. L. M. 8vo, sewed. 6d.

Manual for Gas Engineering Students. By D. LEE. 18mo, cloth 1*s.*

Hydraulic Machinery, Past and Present. A Lecture delivered to the London and Suburban Railway Officials' Association. By H. ADAMS, Mem. Inst. C.E. *Folding plate.* 8vo, sewed, 1*s.*

Twenty Years with the Indicator. By THOMAS PRAY, Jun., C.E., M.E., Member of the American Society of Civil Engineers. 2 vols., royal 8vo, cloth, 12*s.* 6*d.*

Annual Statistical Report of the Secretary to the Members of the Iron and Steel Association on the Home and Foreign Iron and Steel Industries in 1884. Issued March 1885. 8vo, sewed, 5*s.*

Bad Drains, and How to Test them; with Notes on the Ventilation of Sewers, Drains, and Sanitary Fittings, and the Origin and Transmission of Zymotic Disease. By R. HARRIS REEVES. Crown 8vo, cloth, 3*s.* 6*d.*

Standard Practical Plumbing; being a complete Encyclopædia for Practical Plumbers and Guide for Architects, Builders, Gas Fitters, Hot-water Fitters, Ironmongers, Lead Burners, Sanitary Engineers, Zinc Workers, &c. *Illustrated by over* 2000 *engravings.* By P. J. DAVIES. Vol. 1, royal 8vo, cloth, 7*s.* 6*d.*

Pneumatic Transmission of Messages and Parcels between Paris and London, viâ Calais and Dover. By J. B. BERLIER, C.E. Small folio, sewed, 6*d.*

List of Tests (*Reagents*), arranged in alphabetical order, according to the names of the originators. Designed especially for the convenient reference of Chemists, Pharmacists, and Scientists. By HANS M. WILDER. Crown 8vo, cloth, 4*s.* 6*d.*

Ten Years' Experience in Works of Intermittent Downward Filtration. By J. BAILEY DENTON, Mem. Inst. C.E. Second edition, with additions. Royal 8vo, sewed, 4*s.*

A Treatise on the Manufacture of Soap and Candles, Lubricants and Glycerin. By W. LANT CARPENTER, B.A., B.Sc. (late of Messrs. C. Thomas and Brothers, Bristol). *With illustrations.* Crown 8vo, cloth, 10*s.* 6*d.*

The Stability of Ships explained simply, and calculated by a new Graphic method. By J. C. SPENCE, M.I.N.A. 4to, sewed, 3*s.* 6*d.*

Steam Making, or Boiler Practice. By CHARLES A. SMITH, C.E. 8vo, cloth, 10*s.* 6*d.*

CONTENTS:

1. The Nature of Heat and the Properties of Steam—2. Combustion.—3. Externally Fired Stationary Boilers—4. Internally Fired Stationary Boilers—5. Internally Fired Portable Locomotive and Marine Boilers—6. Design, Construction, and Strength of Boilers—7. Proportions of Heating Surface, Economic Evaporation, Explosions—8. Miscellaneous Boilers, Choice of Boiler Fittings and Appurtenances.

The Fireman's Guide; a Handbook on the Care of Boilers. By TEKNOLOG, föreningen T. I. Stockholm. Translated from the third edition, and revised by KARL P. DAHLSTROM, M.E. Second edition. Fcap. 8vo, cloth, 2*s.*

A Treatise on Modern Steam Engines and Boilers, including Land Locomotive, and Marine Engines and Boilers, for the use of Students. By FREDERICK COLYER, M. Inst. C.E., Mem. Inst. M.E. *With 36 plates.* 4to, cloth, 25*s.*

CONTENTS:

1. Introduction—2. Original Engines—3. Boilers—4. High-Pressure Beam Engines—5. Cornish Beam Engines—6. Horizontal Engines—7. Oscillating Engines—8. Vertical High-Pressure Engines—9. Special Engines—10. Portable Engines—11. Locomotive Engines—12. Marine Engines.

Steam Engine Management; a Treatise on the Working and Management of Steam Boilers. By F. COLYER, M. Inst. C.E., Mem. Inst. M.E. 18mo, cloth, 2*s.*

Land Surveying on the Meridian and Perpendicular System. By WILLIAM PENMAN, C.E. 8vo, cloth, 8*s.* 6*d.*

The Topographer, his Instruments and Methods, designed for the use of Students, Amateur Photographers, Surveyors, Engineers, and all persons interested in the location and construction of works based upon Topography. *Illustrated with numerous plates, maps, and engravings.* By LEWIS M. HAUPT, A.M. 8vo, cloth, 18*s.*

A Text-Book of Tanning, embracing the Preparation of all kinds of Leather. By HARRY R. PROCTOR, F.C.S., of Low Lights Tanneries. *With illustrations.* Crown 8vo, cloth, 10*s.* 6*d.*

In super-royal 8vo, 1168 pp., *with 2400 illustrations*, in 3 Divisions, cloth, price 13*s.* 6*d.* each; or 1 vol., cloth, 2*l.*; or half-morocco, 2*l.* 8*s.*

A SUPPLEMENT

TO

SPONS' DICTIONARY OF ENGINEERING.

EDITED BY ERNEST SPON, MEMB. SOC. ENGINEERS.

Abacus, Counters, Speed Indicators, and Slide Rule.
Agricultural Implements and Machinery.
Air Compressors.
Animal Charcoal Machinery.
Antimony.
Axles and Axle-boxes.
Barn Machinery.
Belts and Belting.
Blasting. Boilers.
Brakes.
Brick Machinery.
Bridges.
Cages for Mines.
Calculus, Differential and Integral.
Canals.
Carpentry.
Cast Iron.
Cement, Concrete, Limes, and Mortar.
Chimney Shafts.
Coal Cleansing and Washing.
Coal Mining.
Coal Cutting Machines.
Coke Ovens. Copper.
Docks. Drainage.
Dredging Machinery.
Dynamo - Electric and Magneto-Electric Machines.
Dynamometers.
Electrical Engineering, Telegraphy, Electric Lighting and its practicaldetails,Telephones
Engines, Varieties of.
Explosives. Fans.
Founding, Moulding and the practical work of the Foundry.
Gas, Manufacture of.
Hammers, Steam and other Power.
Heat. Horse Power.
Hydraulics.
Hydro-geology.
Indicators. Iron.
Lifts, Hoists, and Elevators.
Lighthouses, Buoys, and Beacons.
Machine Tools.
Materials of Construction.
Meters.
Ores, Machinery and Processes employed to Dress.
Piers.
Pile Driving.
Pneumatic Transmission.
Pumps.
Pyrometers.
Road Locomotives.
Rock Drills.
Rolling Stock.
Sanitary Engineering.
Shafting.
Steel.
Steam Navvy.
Stone Machinery.
Tramways.
Well Sinking.

London: E. & F. N. SPON, 125, Strand.
New York: 35, Murray Street.

NOW COMPLETE.

ith nearly 1500 *illustrations*, in super-royal 8vo, in 5 Divisions, cloth. ivisions 1 to 4, 13*s.* 6*d.* each ; Division 5, 17*s.* 6*d.* ; or 2 vols., cloth, £3 10*s.*

SPONS' ENCYCLOPÆDIA

OF THE

DUSTRIAL ARTS, MANUFACTURES, AND COMMERCIAL PRODUCTS.

EDITED BY C. G. WARNFORD LOCK, F.L.S.

Among the more important of the subjects treated of, are the lowing :—

ids, 207 pp. 220 figs.
cohol, 23 pp. 16 figs.
coholic Liquors, 13 pp.
kalies, 89 pp. 78 figs.
loys. Alum.
phalt. Assaying.
verages, 89 pp. 29 figs.
icks.
aching Powder, 15 pp.
aching, 51 pp. 48 figs.
ndles, 18 pp. 9 figs.
rbon Bisulphide.
lluloid, 9 pp.
ments. Clay.
al-tar Products, 44 pp.
14 figs.
coa, 8 pp.
ffee, 32 pp. 13 figs.
rk, 8 pp. 17 figs.
tton Manufactures, 62
pp. 57 figs.
ugs, 38 pp.
eing and Calico
Printing, 28 pp. 9 figs.
estuffs, 16 pp.
ectro-Metallurgy, 13
pp.
plosives, 22 pp. 33 figs.
thers.
rous Substances, 92
pp. 79 figs.
or-cloth, 16 pp. 21
igs.
od Preservation, 8 pp.
uit, 8 pp.
Fur, 5 pp.
Gas, Coal, 8 pp.
Gems.
Glass, 45 pp. 77 figs.
Graphite, 7 pp.
Hair, 7 pp.
Hair Manufactures.
Hats, 26 pp. 26 figs.
Honey. Hops.
Horn.
Ice, 10 pp. 14 figs.
Indiarubber Manufactures, 23 pp. 17 figs.
Ink, 17 pp.
Ivory.
Jute Manufactures, 11 pp., 11 figs.
Knitted Fabrics — Hosiery, 15 pp. 13 figs.
Lace, 13 pp. 9 figs.
Leather, 28 pp. 31 figs.
Linen Manufactures, 16 pp. 6 figs.
Manures, 21 pp. 30 figs.
Matches, 17 pp. 38 figs.
Mordants, 13 pp.
Narcotics, 47 pp.
Nuts, 10 pp.
Oils and Fatty Substances, 125 pp.
Paint.
Paper, 26 pp. 23 figs.
Paraffin, 8 pp. 6 figs.
Pearl and Coral, 8 pp.
Perfumes, 10 pp.
Photography, 13 pp. 20 figs.
Pigments, 9 pp. 6 figs.
Pottery, 46 pp. 57 figs.
Printing and Engraving, 20 pp. 8 figs.
Rags.
Resinous and Gummy Substances, 75 pp. 16 figs.
Rope, 16 pp. 17 figs.
Salt, 31 pp. 23 figs.
Silk, 8 pp.
Silk Manufactures, 9 pp. 11 figs.
Skins, 5 pp.
Small Wares, 4 pp.
Soap and Glycerine, 39 pp. 45 figs.
Spices, 16 pp.
Sponge, 5 pp.
Starch, 9 pp. 10 figs.
Sugar, 155 pp. 134 figs.
Sulphur.
Tannin, 18 pp.
Tea, 12 pp.
Timber, 13 pp.
Varnish, 15 pp.
Vinegar, 5 pp.
Wax, 5 pp.
Wool, 2 pp.
Woollen Manufactures, 58 pp. 39 figs.

London: E. & F. N. SPON, 125, Strand.
New York: 35, Murray Street.

Crown 8vo, cloth, with illustrations, 5s.

WORKSHOP RECEIPTS,

FIRST SERIES.

By ERNEST SPON.

SYNOPSIS OF CONTENTS.

Bookbinding.
Bronzes and Bronzing.
Candles.
Cement.
Cleaning.
Colourwashing.
Concretes.
Dipping Acids.
Drawing Office Details.
Drying Oils.
Dynamite.
Electro - Metallurgy — (Cleaning, Dipping, Scratch-brushing, Batteries, Baths, and Deposits of every description).
Enamels.
Engraving on Wood, Copper, Gold, Silver, Steel, and Stone.
Etching and Aqua Tint.
Firework Making — (Rockets, Stars, Rains, Gerbes, Jets, Tourbillons, Candles, Fires, Lances, Lights, Wheels, Fire-balloons, and minor Fireworks).
Fluxes.
Foundry Mixtures.
Freezing.
Fulminates.
Furniture Creams, Oils, Polishes, Lacquers, and Pastes.
Gilding.
Glass Cutting, Cleaning, Frosting, Drilling, Darkening, Bending, Staining, and Painting.
Glass Making.
Glues.
Gold.
Graining.
Gums.
Gun Cotton.
Gunpowder.
Horn Working.
Indiarubber.
Japans, Japanning, and kindred processes.
Lacquers.
Lathing.
Lubricants.
Marble Working.
Matches.
Mortars.
Nitro-Glycerine.
Oils.
Paper.
Paper Hanging.
Painting in Oils, in Water Colours, as well as Fresco, House, Transparency, Sign, and Carriage Painting.
Photography.
Plastering.
Polishes.
Pottery—(Clays, Bodies, Glazes, Colours, Oils, Stains, Fluxes, Enamels, and Lustres).
Scouring.
Silvering.
Soap.
Solders.
Tanning.
Taxidermy.
Tempering Metals.
Treating Horn, Mother-o'-Pearl, and like substances.
Varnishes, Manufacture and Use of.
Veneering.
Washing.
Waterproofing.
Welding.

Besides Receipts relating to the lesser Technological matters and processes, such as the manufacture and use of Stencil Plates, Blacking, Crayons, Paste, Putty, Wax, Size, Alloys, Catgut, Tunbridge Ware, Picture Frame and Architectural Mouldings, Compos, Cameos, and others too numerous to mention.

London: E. & F. N. SPON, 125, Strand.
New York: 35, Murray Street.

Crown 8vo, cloth, 485 pages, with illustrations, 5*s*.

WORKSHOP RECEIPTS,

SECOND SERIES.

By ROBERT HALDANE.

SYNOPSIS OF CONTENTS.

Acidimetry and Alkalimetry.
Albumen.
Alcohol.
Alkaloids.
Baking-powders.
Bitters.
Bleaching.
Boiler Incrustations.
Cements and Lutes.
Cleansing.
Confectionery.
Copying.
Disinfectants.
Dyeing, Staining, and Colouring.
Essences.
Extracts.
Fireproofing.
Gelatine, Glue, and Size.
Glycerine.
Gut.
Hydrogen peroxide.
Ink.
Iodine.
Iodoform.
Isinglass.
Ivory substitutes.
Leather.
Luminous bodies.
Magnesia.
Matches.
Paper.
Parchment.
Perchloric acid.
Potassium oxalate.
Preserving.

Pigments, Paint, and Painting: embracing the preparation of *Pigments*, including alumina lakes, blacks (animal, bone, Frankfort, ivory, lamp, sight, soot), blues (antimony, Antwerp, cobalt, cæruleum, Egyptian, manganate, Paris, Péligot, Prussian, smalt, ultramarine), browns (bistre, hinau, sepia, sienna, umber, Vandyke), greens (baryta, Brighton, Brunswick, chrome, cobalt, Douglas, emerald, manganese, mitis, mountain, Prussian, sap, Scheele's, Schweinfurth, titanium, verdigris, zinc), reds (Brazilwood lake, carminated lake, carmine, Cassius purple, cobalt pink, cochineal lake, colcothar, Indian red, madder lake, red chalk, red lead, vermilion), whites (alum, baryta, Chinese, lead sulphate, white lead—by American, Dutch, French, German, Kremnitz, and Pattinson processes, precautions in making, and composition of commercial samples—whiting, Wilkinson's white, zinc white), yellows (chrome, gamboge, Naples, orpiment, realgar, yellow lakes); *Paint* (vehicles, testing oils, driers, grinding, storing, applying, priming, drying, filling, coats, brushes, surface, water-colours, removing smell, discoloration; miscellaneous paints—cement paint for carton-pierre, copper paint, gold paint, iron paint, lime paints, silicated paints, steatite paint, transparent paints, tungsten paints, window paint, zinc paints); *Painting* (general instructions, proportions of ingredients, measuring paint work; carriage painting—priming paint, best putty, finishing colour, cause of cracking, mixing the paints, oils, driers, and colours, varnishing, importance of washing vehicles, re-varnishing, how to dry paint; woodwork painting).

London: E. & F. N. SPON, 125, Strand.
New York: 35, Murray Street.

JUST PUBLISHED.

Crown 8vo, cloth, 480 pages, with 183 illustrations, 5*s*.

WORKSHOP RECEIPTS

THIRD SERIES.

By C. G. WARNFORD LOCK.

Uniform with the First and Second Series.

SYNOPSIS OF CONTENTS.

Alloys.	Indium.	Rubidium.
Aluminium.	Iridium.	Ruthenium.
Antimony.	Iron and Steel.	Selenium.
Barium.	Lacquers and Lacquering.	Silver.
Beryllium.	Lanthanum.	Slag.
Bismuth.	Lead.	Sodium.
Cadmium.	Lithium.	Strontium.
Cæsium.	Lubricants.	Tantalum.
Calcium.	Magnesium.	Terbium.
Cerium.	Manganese.	Thallium.
Chromium.	Mercury.	Thorium.
Cobalt.	Mica.	Tin.
Copper.	Molybdenum.	Titanium.
Didymium.	Nickel.	Tungsten.
Electrics.	Niobium.	Uranium.
Enamels and Glazes.	Osmium.	Vanadium.
Erbium.	Palladium.	Yttrium.
Gallium.	Platinum.	Zinc.
Glass.	Potassium.	Zirconium.
Gold.	Rhodium.	

London: E. & F. N. SPON, 125, Strand.

New York: 35, Murray Street.

WORKSHOP RECEIPTS,

FOURTH SERIES,

DEVOTED MAINLY TO HANDICRAFTS & MECHANICAL SUBJECTS.

By C. G. WARNFORD LOCK.

250 Illustrations, with Complete Index, and a General Index to the Four Series, 5s.

Waterproofing — rubber goods, cuprammonium processes, miscellaneous preparations.

Packing and Storing articles of delicate odour or colour, of a deliquescent character, liable to ignition, apt to suffer from insects or damp, or easily broken.

Embalming and Preserving anatomical specimens.

Leather Polishes.

Cooling Air and Water, producing low temperatures, making ice, cooling syrups and solutions, and separating salts from liquors by refrigeration.

Pumps and Siphons, embracing every useful contrivance for raising and supplying water on a moderate scale, and moving corrosive, tenacious, and other liquids.

Desiccating—air- and water-ovens, and other appliances for drying natural and artificial products.

Distilling—water, tinctures, extracts, pharmaceutical preparations, essences, perfumes, and alcoholic liquids.

Emulsifying as required by pharmacists and photographers.

Evaporating—saline and other solutions, and liquids demanding special precautions.

Filtering—water, and solutions of various kinds.

Percolating and Macerating.

Electrotyping.

Stereotyping by both plaster and paper processes.

Bookbinding in all its details.

Straw Plaiting and the fabrication of baskets, matting, etc.

Musical Instruments—the preservation, tuning, and repair of pianos, harmoniums, musical boxes, etc.

Clock and Watch Mending—adapted for intelligent amateurs.

Photography—recent development in rapid processes, handy apparatus, numerous recipes for sensitizing and developing solutions, and applications to modern illustrative purposes.

London: E. & F. N. SPON, 125, Strand.

New York: 35, Murray Street.

JUST PUBLISHED.

In demy 8vo, cloth, 600 pages, and 1420 Illustrations, 6*s*.

SPONS'

MECHANICS' OWN BOOK;

A MANUAL FOR HANDICRAFTSMEN AND AMATEURS.

CONTENTS.

Mechanical Drawing—Casting and Founding in Iron, Brass, Bronze, and other Alloys—Forging and Finishing Iron—Sheetmetal Working —Soldering, Brazing, and Burning—Carpentry and Joinery, embracing descriptions of some 400 Woods, over 200 Illustrations of Tools and their uses, Explanations (with Diagrams) of 116 joints and hinges, and Details of Construction of Workshop appliances, rough furniture, Garden and Yard Erections, and House Building—Cabinet-Making and Veneering — Carving and Fretcutting — Upholstery — Painting, Graining, and Marbling — Staining Furniture, Woods, Floors, and Fittings—Gilding, dead and bright, on various grounds—Polishing Marble, Metals, and Wood—Varnishing—Mechanical movements, illustrating contrivances for transmitting motion—Turning in Wood and Metals—Masonry, embracing Stonework, Brickwork, Terracotta, and Concrete—Roofing with Thatch, Tiles, Slates, Felt, Zinc, &c.— Glazing with and without putty, and lead glazing—Plastering and Whitewashing — Paper-hanging — Gas-fitting—Bell-hanging, ordinary and electric Systems — Lighting — Warming — Ventilating — Roads, Pavements, and Bridges — Hedges, Ditches, and Drains — Water Supply and Sanitation —Hints on House Construction suited to new countries.

London: E. & F. N. SPON, 125, Strand.

New York: 35, Murray Street.

APR 1 0 1952